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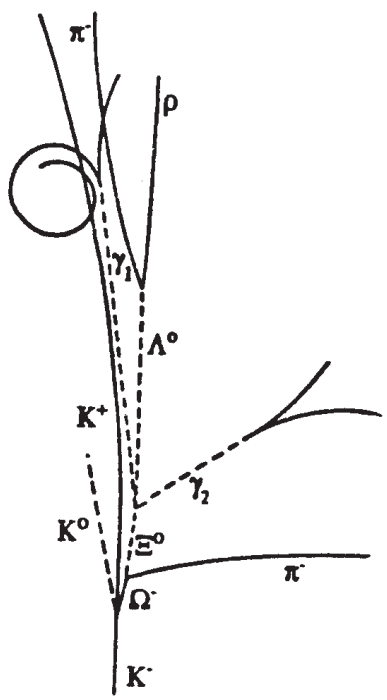

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STUDY OF THE ELECTROMAGNETIC CONTENT OF SANTILLI'S THREE BODY STRUCTURE MODEL OF THE DEUTERON AND ITS IMPLICATIONS FOR NEW NUCLEAR ENERGIES

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Abstract

According to the traditional models, like e.g. the Standard Model (SM), the deuteron is formed by a proton plus a neutron. Like shown by Hadronic Mechanics (HM) this formulation is not at all satisfactory and does not explain the mass and magnetic moment deficits, nor the experimental value of the strong interaction constant. Moreover, it is not consistent with the results of experiments of photodis-

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integration of the deuteron and lacks a fundamental milestone: how is it that the deuteron is stable, in spite of the noted instability of the neutron? Here we propose a radically innovative approach, i.e. a relativistic and dynamic model, according to which the deuteron is formed by three particles (two protons and an electron) that conveniently rotate round their center of mass. The model defines a stable bounded state that explains the observed values of the mass and magnetic moment as well as of the spin. In addition, it points out that the strong interaction is electromagnetic (the coupling constant has value $g_d = 14$, in accordance with experimental findings). The nuclear force is electromagnetic and it is counteracted by an inertial force (the centrifugal force). A nuclear reaction can be activated by breaking the deuteron with a photon having energy $193\,MeV$. Such value corresponds to a minimum of the measured cross-section.

The model satisfactorily explains all of the principle ways of decomposition of the deuteron, in particular the observed bearing of particles η, ρ, Δ, π, η', N. The proposed structure is compared with Santilli "hadronic structure of the deuteron".

List of Symbols

α	fine structure constant;
c	speed of light in empty space;
ε_0	permittivity in vacuum;
$k = 1/4\pi\varepsilon_0$	Coulomb constant;
μ_0	magnetic permeability in vacuum;
m_0	electron mass;
q	unitary charge;
h	Planck constant
m_p, m_n, m_d, m_D	mass of proton, neutron, deuterium, deuteron;
$\mu_p, \mu_n, \mu_d, \mu_D$	magnetic moment of proton, neutron, deuterium, deuteron;
E_p, E_k, E_B, E_H	energy, potential, kinetic, binding, electromagnetic.

1 Introduction

The author assumes Hadronic Mechanics (HM) as foundation, in particular Santilli's three body model of the deuteron with proved causality etc. for fractional angular momenta; then the author enters into the study of the electromagnetic component of Santilli's model. We briefly recall the following.

1.1 Santilli's structure model of the neutron as a hadronic bound state of a proton and an electron

In two seminal memoirs of 1978 [1,2], the Italian-American physicist Ruggero Maria Santilli identified the foundation of and proposed the completion of the construction of a nonunitary, isotopic (axiom-preserving) covering of quantum mechanics under the name of hadronic mechanics for novel representations of the structure of hadrons, nuclei and stars with extended, thus deformable constituents in conditions of partial or total mutual immersion.

The latter basic assumption implies the admission of conventional action-at-a-distance potential, thus Hamiltonian interactions, as well as potential, therefore nonhamiltonian interactions originating from the assumed mutual penetration. In turn, the Hamiltonian character implies the central feature that the time evolution of hadronic mechanics is characterized by a nonunitary transformation.

Santilli was well aware that, when formulated on conventional Hilbert spaces over s conventional. field of complex numbers, nonunitary time evolutions violate causality and other basic laws. To resolve this historical impasse, Santilli achieved a new mathematics, today known as isomathematics, that indeed reconstructs linearity, thus causality and other laws on certain isotopic images of the Hilbert space defined on certain generalized fields with an arbitrary, generally integro-differential basic unit, called isounit.

To illustrate the validity of the proposed hadronic mechanics, Santilli achieved in Section 5 of ref. [2] the first known quantitative representation of all characteristics of the π^0 particle as a bound state of an electron and

a positron originating from the known synthesis

$$e^+ + e^- \to \pi^0.$$

Such a model is impossible for quantum mechanics because the rest energy of the π^0 is about $133\,MeV$ bigger than the sum of the rest energy of the constituents, thus requiring a "positive" binding energy, under which conditions the Schrödinger equation no longer admits physically consistent solutions. In fact, the only consistent bound states predicted by quantum mechanics are those with a "negative" binding energy, as it is the case for quantum bound states in particle, nuclear and molecular physics.

Santilli was able to achieve consistency precisely in view of the nonunitary structure of hadronic mechanics. In particular, the consistency mechanism achieved for the first time [2] is that contact nonuniform interactions cause a new renormalization (which he called mutation), this time of the intrinsic characteristics of the constituents , such as mass, spin and other characteristics. As shown in Sect. 5 of ref. [2], one single nonunitary lifting of Schrödinger equation (today known as the Schrödinger-Santilli isoequation) provides the numerically exact representation the rest energy, charge radius, meanlife, spin, parity and spontaneous decay with the highest mode

$$\pi^0 \to e^+ + e^-.$$

As a matter of fact, Santilli argues that the physical constituents of the π^0 meson are one electron and one positrons precisely because of the above primary decay, and concluded by stating that hadronic mechanics permits a consistent representation of the π^0 meson as a "compressed positronium."

Hadronic mechanics had been proposed [1,2] for the primary purpose of representing the synthesis of the neutron inside stars from a proton and an electron according to Rutherford

$$p^+ + e^- \to n + \nu.$$

In this case too, the rest energy of the neutron is $0.782\,MeV$ bigger than the sum of the rest energies of the proton and of the electron, thus preventing any consistent use of quantum treatments. However, the problem of the structure of the neutron was dramatically more complex than that of the

π^0 because of complex issues pertaining of spin. Therefore, as a necessary prerequisite to solve the problem of the neutron synthesis, Santilli had to spend decades of research to work out in details isomathematics, with particular reference to the nonunitary isotopies of Lie's theory (today known as the Lie-Santilli isotheory) we cannot possibly review in this paper (see monographs [10-12] for brevity).

Finally, after all this preparatory work, Santilli was able to achieve in 1990 [3] the first known nonrelativistic representation of all characteristics of the Tyrone as a "compressed hydrogen atom" according to Rutherford, namely, as a hadronic bound state of a proton and an electron in conditions of total mutual immersion, thus verifying the nonunitary - isotopic laws of hadronic mechanics. In this way, again, one single Schrödinger-Santilli equation allowed the representation of "all" characteristics of the neutron, including rest energy, charge radius, meanlife, spin, parity, anomalous magnetic moment and primary spontaneous decay

$$n \to p^+ + e^- + \bar{\nu}.$$

Again Santilli argued that, by keeping in mind synthesis the above spontaneous decay identifies the proton and the electron as the most plausible constituents of the neutron.

Finally, Santilli achieved in 1995 [4] the first known nonrelativistic representation of all characteristics of the neutron in its synthesis from a proton and an electron inside a star. The main tool was the nonunitary isotopic lifting of Dirac equation today known as the Dirac-Santilli isoequation.

Santilli then concluded his studies on the structure of the neutron via an experimental confirmation of the historical Borghi experiment on the laboratory synthesis of the neutron from hydrogen [5]. A readable review of three decades of mathematical, theoretical and experimental research on the neutron synthesis and structure is provided by J.V. Kadeisvili [6].

An aspect of these studies of central relevance for this paper is the representation of the neutron spin via the use of the orbital angular momentum of the electron when trapped inside the proton, thus being constrained to orbits with an angular momentum equal to the proton spin. It then follows that the total angular momentum of the electron compressed inside the proton is identically null due to the singlet coupling necessary for stability, and

the spin of the neutron coincides with that of the proton. Such an orbital motion of the electron also allows a numerically exact representation of the neutron anomalous magnetic moment.

In essence, Santilli [3-6] argued that, during Fermi's time, the proton could solely be conceived as a dimensionless point, as it is the case to this day for the rigorous application of quantum mechanics. Consequently, no orbital motion of the electron is possible in synthesis since quantum mechanics solely admits the quantized orbits of the hydrogen atoms. When the proton is admitted as it is in the physical reality, a large and hyperdense charge distribution according to particle standard, there is the emergence of the orbital angular momentum, this time for the electron constrained inside the proton.

One of the consequence of the model is the lack of existence of the neutrino as a physical particle in our spacetime, and its replacement with a longitudinal impulse propagating through the ether, called by Santilli [7] the etherino and represented with the symbol "a" that transfers the missing energy, spin and other features from the ether to the neutron according to the reaction

$$p^+ + a + e^- \to n.$$

In essence, Santilli argued that, in the event the energy of $0.782\,MeV$ missing for the synthesis of the neutron inappropriate from the star environment, it would be impossible for a star to initiate the production of light because there would be the need for at least $10^{50} MeV$ per seconds. In fact, starting from a hydrogen gas, the first synthesis is that of the neutron that requires energy, to be followed then by the synthesis of nuclei that releases energy. The most plausible solution suggested by Santilli is that the missing energy originates from the ether as a universal substratum with a very large energy density. The etherino is the impulse transmitting from the ether to the neutron not only the missing energy, but also spin and other characteristics.

If is evident that, without such a model there is no possibility for a consistent introduction of the neutrino as a physical particle in our spacetime due to the impossibility of identifying the origin of its main features such as mass, spin, etc.

1.2 Santilli structure model of the deuteron as a hadronic bound state of two protons and one electron

After resolving the problem of the structure of the neutron, Santilli passes to its most important application, the formulation of a basically new model on the structure of nuclei beginning with the simplest possible nucleus, the deuteron. The evident main aim of the studies for which Santilli proposed the hadronic mechanics [1,2] is the reduction of all known matter to the only stable particles we know, the proton and the electron.

As it is well known, the first historical hypothesis on the structure of nuclei formulated immediately after their discovery was that nuclei are bound states of protons and electrons. However, fundamental inconsistencies soon emerged under the use of the mechanics available at that time, quantum mechanics, such as the impossibility of representing the energy, spin, magnetic moment and other basic features of nuclei when considered as quantum mechanical bound states of protons and electrons.

A first important contribution by Santilli for the nuclear structure (which is a direct consequence of the prior achievement of the structure of the neutron as a hadronic bound state of a proton and an electron) is that all historical inconsistencies for nuclei composed of protons and electrons are resolved by the covering hadronic mechanics thanks precisely to its nonunitary structure.

A second important contribution by Santilli in nuclear physics, which was achieved in the original memoirs of 1978 [1,2], has been the discovery that contact, nonunitary, thus nonhamiltonian interactions cause a strongly attractive force for extended spinning and deformable particles in singlet coupling. When such a strongly attractive force is projected in a conventional Hilbert space, it can be represented via a conventional Hulten potential. Particularly important for this paper is the fact that the Hulten potential essentially coincides with the Coulomb potential at distances of the order of $1\,fm$, *thus allowing the study of the electromagnetic contribution presented in this paper.*

In different words, according to hadronic mechanics, the strong nuclear forces has a primary origin of contact, nonpotential nonhamiltonian and,

therefore, of nonunitary character that, *in first approximation*, can be reduced to electromagnetic interactions, thus illustrating the foundations of the analysis of this paper.

A third important contribution by Santilli to nuclear physics has dating back to 1978 been the notion of mutation of elementary particles, namely, the alteration of their intrinsic characteristics under contact nonunitary interactions. In essence, Santilli argues that, following one century of research, quantum mechanics has been unable to achieve a meaningful representation of nuclear magnetic moments. In Santilli's view, this is a consequence of the experimentally unverified conjecture that, when members of a nuclear structure, protons and neutrons have exactly the same intrinsic characteristics as when in vacuum under long range electromagnetic interactions.

Santilli considers the latter assumption as unrealistic because, due to the strength of strong nuclear forces, the more plausible assumption is that the proton and the neutron should at least experience a deformation/mutation of their charge distribution. Once suite a deformation is admitted, the exact representation of the magnetic moment of all nuclei is elementary because a deformation of the charge distribution for spinning particles causes a corresponding deformation of their intrinsic magnetic moment.

As a matter of fact, Santilli considers a theory as being exactly valid for given conditions only when it represents "all" experimental data. In the event only one experimental value is not represented, the theory cannot be considered as being exact for the conditions considered on any serious ground. But quantum mechanics has been unable to represent spins, magnetic moments and other nuclear features following one century of efforts. Consequently, quantum mechanics cannot be considered as being exact for the nuclear structure. The covering hadronic mechanics is the only known theory at this writing which represents all nuclear data in a numerically exact and time invariant form.

Following the above foundations, Santilli proceeded to the construction of his structure model of the deuteron as a hadronic bound state of two protons and one electron (see figure 1). For this purpose, he first identified the insufficiency of the quantum representations that can be summarized as follows [12].

1.3 Critical analysis of conventional Quantum Mechanics according to Hadronic Mechanics

(1) Quantum mechanics has been unable to represent the stability of the deuteron. This is evidently due to the natural instability of the deuteron. The unsolved problem is due to the absence in the technical literature of quantitative numerical proofs that, when bonded to a proton, the neutron cannot decay, as an evident condition for stability. Except for philosophical-political statements, the stability of the deuteron has been left fundamentally unexplained by quantum mechanics to this day.

(2) Quantum mechanics has been unable to represent the spin 1 of the ground state of the deuteron. The basic axioms of quantum mechanics require that the most stable bound state of two particles with the same spin is that with *spin zero*. No such state has been detected in the deuteron. Therefore, following one century of research, quantum mechanics has been unable to represent the spin 1 of the ground state of the deuteron except, again, for political-nonscientific views (see Figure 1 for more details).

(3) Quantum mechanics has been unable to reach an exact representation of the magnetic moment of the deuteron. After about one century of research, nonrelativistic quantum mechanics misses 0.022 *Bohr units* corresponding to 2.6% of the experimental value. Relativistic corrections reduce the error down to about 1% but under highly questionable theoretical assumptions, such as the use for ground state of a mixture of different energy levels that are assumed to exist without any emission or absorption of quanta as requested by quantum mechanics. Embarrassing deviations occur for the magnetic moments of heavier nuclei.

(4) Quantum mechanics has been unable to identify the physical origin of the attractive force binding together the proton and the neutron in the deuteron. Since the neutron is neutral, there is no known electrostatic origin of the attractive force needed for the existence of the deuteron.

As a matter of fact, the only Coulomb force for the proton-neutron system is that of the magnetic moments, which force is *repulsive* for the case of spin 1 with parallel spin. Therefore, a "strong" force was conjectured and its existence was subsequently proved to be true. Nevertheless, the physical origin of such strong force has remained unidentified following one century of research via quantum mechanics. Particularly mysterious remain the "exchange forces," namely, forces originating from the exchange of protons and neutrons.

(5) Quantum mechanics has also been unable to treat the deuteron space parity in a way consistent with the rest of the theory. The experimental value of the space parity of the deuteron is positive for the ground state, because the angular momentum L is null. However, in the dream of achieving compatibility of the deuteron phenomenology with quantum mechanics, nuclear physicists assume for the calculation of the magnetic moment that the ground state is a mixture of the lowest state with $L = 0$ with other states in which the angular momentum is not null, thus implying an embarrassing incompatibility of these calculations with the positive parity of the ground state.

In conclusion, after about one century of research, quantum mechanics has left unresolved fundamental problems even for the case of the smallest possible nucleus, the deuteron, with progressively increasing unresolved problems for heavier nuclei. Following these insufficiencies, any additional belief on the final character of quantum mechanics in nuclear physics is a sheer political posture in disrespect of the societal need to search for a more adequate mechanics.

1.4 Our contribution

We illustrate a study of the electromagnetic content of Santilli's three body structure model of the deuteron and its implications for new nuclear energies. Santilli showed the Hulten potential essentially coincides with the coulomb potential at distances of the order of $1\,fm$, thus allowing the study of the electromagnetic contribution presented in the following. In different words according to Hadronic Mechanics the strong nuclear forces can be

reduced, in first approximation, to electromagnetic interactions. This represents the basis of our novel approach, together with the use of dynamic models. The deuteron is reduced to three rotating point particles, two of which represent protons and the third an electron. In reality the point particle representing a proton is the center of mass of a planar structure containing a bi-dimensional three-quark proton. The plane of the planar structure is inclined with respect to the plane of the three point particles so that in the final analysis the deuteron has a three dimensional dynamical structure.

We soon say that the use of dynamic models which are in dynamical equilibrium makes irrelevant the seeming insufficiency that the elm forces are repulsive (two protons against one electron, including both charge and magnetic moments). We have already said about the second seeming insufficiency that is, in the event the model is correct all nuclear forces can be reduced to pure elm interactions. Such conclusion has been disproved repeatedly over one century, but here we represent it in a novel light thanks to the use of dynamical models, so that in reality the nuclear force is electromagnetic plus inertial.

According to traditional models, like e.g. the Standard Model of Particle Physics (SM), a deuteron is formed by a proton plus a neutron (figure 2(a)). The unconsistency of such model was first shown by R. Santilli and led to formulation of "Santilli hadronic structure of the deuteron". He showed that the deuteron is a three body system and that the spin is 1. The most plausible possibility is that the deuteron is composed of two protons and one electron. Before achieving such result it is necessary to achieve a structure model of the neutron as a bound state of a proton and an electron.

That being stated we soon say that the approach illustrated in our work is inspired to HM as regards the idea that the deuteron is a three-body structure, but substantially differs from it as regards the mathematical models used to represent the protons and the deuteron as a whole. Indeed we make reference to dynamic rather than static models and make appeal to electromagnetism and to stability theory to characterize the binding energy. According to a proposal made by Di Caprio in 2000 [21] the proton is a stable dynamic structure made up by three quarks (u, s, d) plus a pion. Such particles rotate synchronously round their center of mass within a plane. The

equivalence energy/mass represents the fundamental assumption underlying such model and explains how it is that small particles (the quarks) can give origin to the proton mass (938.27 MeV). On the other hand the quarks are in dynamical equilibrium, and stability of such equilibrium assures that the proton is a bound state like in HM. Here we propose a dynamical model of the whole deuteron by postulating that each proton (i.e. each of the corresponding planes) rotates around a vertical axis which passes through the electron. This defines a three-dimensional structure which by convenient assumptions is stable. In our formulation "stability" is the conceptual equivalent of "state boundedness" in HM. However we are not obliged, like in HM, to make intermediate step as e.g. the definition of the neutron as a bound state formed by a proton and an electron. We fully share the conjecture that the neutron had indeed such kind of structure, but thanks to stability theory are able to avoid the effective use of such intermediate step. Further on: since a rotating charge generates a magnetic field our approach leads us to recognize that each of two protons of the deuteron generates a magnetic field and, in addition, inside the deuteron the proton fields are rotating fields. By this way we reach the conclusion that the binding energy is electromagnetic and the strong interaction constant equals about 14.

Our study starts with the following considerations: the deuteron mass is smaller than the sum of the masses of the proton and neutron; furthermore, the magnetic moment is different from the sum of the corresponding magnetic moments. Indeed we have

$$\begin{aligned} m_d &= 1875.57\,MeV\,; \quad m_p = 938.27\,MeV\,; \quad m_n = 939.56\,MeV \\ \mu_d &= 0.857\,(q\hbar/2m_p)\,; \quad \mu_p = 2.7928\,(q\hbar/2m_p)\,; \quad \mu_n = -1.913\,(q\hbar/2m_p) \end{aligned}$$

$$\begin{aligned} m_p + m_n &= 1877.8\,MeV \\ \mu_p + \mu_n &= 0.8798\,(q\hbar/2m_p) \end{aligned}$$

and the Standard Model points out a seeming mass deficit

$$\Delta m = 1875.57\,MeV - 1877.8\,MeV = -2.26\,MeV$$

and a seeming magnetic moment deficit

$$\Delta\mu = (0.857 - 0.8798)\,(q\hbar/2m_p) = -0.0228\,(q\hbar/2m_p)\,.$$

As we shall prove, such relations simply implicate that the SM is unsatisfactory even though it correctly reproduces the electric charge and the spin. In addition, the SM does not explicitly clarify how the two particles (proton and neutron) stay together nor, even less, does it explain the stable character of the tie. Another moot point is the definition of the nature of binding energy E_B. In fact, it is postulated that such energy is negative and equal to $\Delta m \cdot c^2 = -2.26\,MeV$. The absurdity of this assumption does not need to be emphasized and will emerge in the full light of our analysis. At the moment, we may note that E_B cannot be other than positive and, as a matter of fact, the photodisintegration experiments of the deuteron described in [13] contemplate positive (breaking) energies only. On the other hand, the various ways of decomposition observed in such tests are simply unexplicated by the SM. Here we propose a concrete alternative, which is based on entirely innovative theoretical foundations. To introduce the subject we preliminarily note that as shown in [34] a neutron consists of an electron in rotation around a proton (figure 4). Starting from there and developing the elementary idea that the deuteron is formed by a proton in rotation around a neutron, one arrives, in final analysis, at a dynamical model of a deuteron seen as a composite dynamic system formed by two protons and one "intermediate" electron in convenient rotation around their center of mass.

HM poses the problem of deuteron stability, while there is no credible proof in scientific literature as to the reason why a member of the stable deuteron, the *unstable* neutron, is turned into a stable particle with an infinite lifetime. Furthermore, it solves the problem of the spin which is 1 and not zero, as predicted by quantum mechanics. Thirdly, it clarifies that the nuclear force is the sum of a *potential* force due to charge and magnetic moments, and of the *non-potential* force due to wave overlapping. The deuteron binding energy $E_d = 2.26\,MeV$ is due to the potential component of the deuteron binding force.

The above views are considered of crucial importance by the author. It has already been shown [21,22] that the subnuclear forces in the proton

are electromagnetic and inertial (figure 3(b)) (*gluons do not exist*, see figure 3(a)) and that quantization of the electron's orbits in hydrogen represents an effect of stability. Also, [34] the neutron can be represented by a dynamical model (proton + a revolving electron) which innovates the static model of HM and explains the physical meaning of the neutrino and the value of its energy.

Here we illustrate an analogous extension (from *statics* to *dynamics*) for deuteron. We rely on the following theoretical elements.

(1) Force, mass, magnetic moment are *relativistic* and *dynamical* quantities. In particular, there exists a purely electromagnetic contribution to mass which is equal to $193\,MeV/c^2$ and represents the inertial effect of the Binding Energy $E_B = 193\,MeV$. In order to break the deuteron it is sufficient to hit it with a photon (or any particle) having a similar amount of energy; the break gives origin to a chain nuclear reaction. The freed energy is clean.

(2) Stability theory allows us to show that a deuteron is indeed a *bounded stable state*. Stability analysis is referred to conditions of "Dynamical Equilibrium", in which the centrifugal force counteracts the electromagnetic force. This is an original formulation that finds correspondence in gravitational problems.

(3) We make use of the fundamental principle of equivalence, Potential energy/mass.

(4) We discover the effective character of the nuclear force, which is electromagnetic plus inertial.

(5) We get the result by elementary mathematics, without encountering problems of isonormalization. This seems to indicate that HM could be improved in a meaningful way.

So, we may assume that the basic properties of deuteron can be represented by a dynamical model in which two protons and one electron conveniently rotate around their center of mass.

The problem is to determine the parameters of such a model so that the above deficits of mass and magnetic moments are explained. In addition, the spin must be equal to $\hbar$ and the electric charge equal to q. We decompose the problem into three sub-problems and use a general result descending from the study of two-body relativistic stability [24] to show that if the three bodies rotate synchronously then the maximum rotation speed allowed by stability is

$$v_{rot} = v_{\max} = \left(\frac{\sqrt{5}-1}{2}\right)^{1/2} c = 0.78615\, c \tag{1}$$

with c the speed of light in vacuum. The corresponding relativistic coefficient equals

$$\gamma_{rot} = \gamma_{\max} = \frac{1}{\sqrt{1-(v_{\max}^2/c^2)}} = \frac{\sqrt{5}+1}{2} = 1.618 \tag{2}$$

and $\gamma_{\max}, v_{\max}$ satisfy

$$\gamma_{\max}\frac{v_{\max}^2}{c^2} = 1 \tag{3}$$

We show in the Appendix that for the deuteron three-body problem the condition

$$\frac{\gamma\, v^2}{c^2} = 1$$

is sufficient for stability. For details see the Appendix.

The subsequent presentation is organized in the following way: Sec. 2: Description of the postulated dynamic structure of the proton and derivation of the numerical parameters. Check of the mass condition and of the magnetic moment condition. Sec. 3: Definition of the binding energy and calculation of the strong interaction constant. Sec. 4: Spin and electric charge. Sec. 5: Conditions of dynamical Equilibrium along each of the three orbits. Proof that the nuclear force is electromagnetic and that it is balanced by the centrifugal force. Sec. 6: Illustration of various theoretical ways of decomposition of the deuteron by hitting it with energized photons.

Comparison with noted experiments. Possibility of triggering a chain reaction at an energy level $193\,MeV$ equal to the value of the binding energy. Sec. 7: Proof that the center of mass coincides with the geometric center. Sec. 8: Proof that a problem of radiation does not exist. Sec. 9: Discussion of the mathematical and physical relevance of the proposed solution. Sec. 10: Preventive answer to foreseeable objections. Sec. 11: Conclusion.

2 Dynamical structure of a deuteron

We postulate that the deuteron consists of two protons p_1, p_2 (conventionally denominated "external proton" and "antipodic proton") plus an "intermediate" electron, in circular rotation around their center of mass within a plane Π_d (figure 2(b)). The rotations are synchronous and, at any time proton p_1 is distant R_1 from the center O, proton p_2 is at the antipodes of p_1, at a distance R_2 from O, with $R_2 < R_1$. The electron is in turn at the antipodes of p_1 (and then is aligned with p_2) at a distance R_3 from O such that $R_3 < R_2 < R_1$. Denoting V_1, V_2, V_3 the three rotation speeds we assume

$$V_1 = const\,; \quad V_2 = const\,; \quad V_3 = const \tag{4}$$

$$\frac{V_3}{R_3} = \frac{V_2}{R_2} = \frac{V_1}{R_1}\ (synchrony). \tag{5}$$

Another fundamental assumption based upon collateral studies [21,34], is that each of the two protons is a composite particle formed by three rotating quarks plus a pion, contained within a plane. We assume that planes Π_1 and Π_2 respectively containing p_1 and p_2 form an angle $\psi = 30^o$ with plane Π_d of the deuteron (i.e. the horizontal plane of motion of the "point-form" particles p_1, p_2, e). We also assume that in the three-dimensional structure of the deuteron the electron remains pointform (within an approximation of $10^{-19}\,m$) and that its spin and its magnetic moment are perpendicular to Π_d. At any time the center of mass of composite particle p_1 belongs to the intersection of Π_1 with Π_d and represents a mobil point on the circle with radius R_1 and center O (in plane Π_d). Analogously, the center of mass of composite particle p_2 belongs to intersection of Π_2 with Π_d and represents a mobil point on a circle with radius R_2 and center O (in plane Π_d). All in

all, the deuteron has a *three-dimensional structure* (figure 5) and in plane Π_d the distance between the centers of mass of the two protons is in the order $10^{-18}m$. It is clear that no overlapping among particles exists in spite of the fact the proton radius (which is about $1.4 \cdot 10^{-15}m$) is larger than the *distance* between Π_1 and Π_2.

We call *solution of the deuteron problem* any set of values R_1, R_2, R_3, V_1, V_2, V_3, ψ so that the three-body structure in object gives the experimental values of charge, mass, magnetic moment, spin of the deuteron. In addition we want to explain the character of the strong interaction and the experimental value $g_d \sim 14$. Furthermore, we require that the three-body dynamic structure in object be *stable*.

To solve the problem, we use relativistic equations derived from Special Relativity (SR) and the principle of equivalence Potential energy/mass. In particular, for each particle we determine its contribution to the total mass by equations of type

$$\hat{m} = \gamma \left(m + \frac{E_p}{c^2} \right)$$

where γ is the relativistic coefficient

$$\gamma = \frac{1}{\sqrt{1 - (v^2/c^2)}}$$

and E_p is the Coulomb potential energy. So we have three distinct contributions, one for each particle and, in vie of determining total mass we add a fourth contribution (E_H/c^2) that accounts for the inertial effects of the binding electromagnetic energy. The meaning of E_H is explained in Sec. 3. All in all, the mass of the deuteron is given by

$$m_d = (m_1 + m_2 + m_3) + m_4 \tag{6}$$

$$\begin{aligned} m_1 &= \gamma_1 \left[m_p + \frac{E_{12}}{c^2} + \frac{E_{13}}{c^2} \right] ; \quad m_2 = \gamma_2 \left[m_p + \frac{E_{12}}{c^2} + \frac{E_{23}}{c^2} \right] \\ m_3 &= \gamma_3 \left[m_0 + \frac{E_{13}}{c^2} + \frac{E_{23}}{c^2} \right] ; \quad m_4 = \frac{E_H}{c^2} \end{aligned} \tag{7}$$

$$E_{12} = \frac{kq^2}{R_1 + R_2}\,; \quad E_{13} = -\frac{kq^2}{R_1 + R_3}\,; \quad E_{23} = -\frac{kq^2}{R_2 - R_3} \tag{8}$$
$$\left(k = \frac{1}{4\pi\varepsilon_0}\,; \quad \varepsilon_0 \ \textit{pemittivity in vacuum}\right).$$

The rotation speed of p_1 is the maximum allowed by stability (see Sec. 1)

$$V_1 = v_{\max} = 0.78615\,c \tag{9}$$

while the rotation speeds of the other two particles are determined by the isochrony condition (5):

$$V_2 = V_1 \cdot \frac{R_2}{R_1}\,; \qquad V_3 = V_1 \cdot \frac{R_3}{R_1}\,. \tag{10}$$

The relativistic coefficients γ_1, γ_2, γ_3 are given by

$$\gamma_1 = \frac{1}{\sqrt{1 - V_1^2/c^2}} = \gamma_{\max} = 1.618 \tag{11}$$
$$\gamma_2 = \frac{1}{\sqrt{1 - V_2^2/c^2}}\,; \qquad \gamma_3 = \frac{1}{\sqrt{1 - V_3^2/c^2}}\,.$$

We claim that the following set of values identifies a *solution of the deuteron problem*

$$R_1 = 8.955 \cdot 10^{-18} m\,; \quad R_2 = 4.835 \cdot 10^{-18} m\,; \quad R_3 = 0.915 \cdot 10^{-18} m \tag{12}$$
$$V_1 = 0.78615 \cdot c\,; \qquad V_2 = 0.42446 \cdot c\,; \qquad V_3 = 0.0803 \cdot c \tag{13}$$

$$\psi = 0.786\ rad\,. \tag{14}$$

In fact, they give us

$$E_{12} = \frac{kq^2}{R_1 + R_2} = 104.41\,MeV \tag{15}$$
$$E_{13} = -\frac{kq^2}{R_1 + R_3} = -145.9\,MeV$$
$$E_{23} = -\frac{kq^2}{R_2 - R_3} = -367.3\,MeV$$

$$\gamma_1 = 1.618\,; \qquad \gamma_2 = 1.1044\,; \qquad \gamma_3 = 1.0032\,. \tag{16}$$

Moreover, (see Sec. 3) the electromagnetic energy E_H turns out equal to

$$E_H = 193\,MeV. \tag{17}$$

Then

$$\begin{aligned} m_1 &= \gamma_1\,[938.27 + 104.46 - 145.9]\;MeV/c^2 = \gamma_1 \times 896.83\,MeV/c^2 \\ m_2 &= \gamma_2\,[938.27 + 104.46 - 367.33]\;MeV/c^2 = \gamma_2 \times 675.39\,MeV/c^2 \\ m_3 &= \gamma_3\,[0.511 - 145.9 - 367.33]\;MeV/c^2 = \gamma_3 \times (-512.72)\,MeV/c^2 \end{aligned}$$

$$\begin{aligned} m_1 + m_2 + m_3 &= 1.618 \times 896.83 + 1.1044 \times 675.39 \\ &\quad +1.0032 \times (-512.72) \\ &= 1682.57\;MeV/c^2 \end{aligned} \tag{18}$$

$$\begin{aligned} (m_1 + m_2 + m_3) + m_4 &= (1682.57)\,MeV/c^2 + E_H/c^2 \\ &= 1875.57 MeV/c^2 \equiv m_d\,. \end{aligned} \tag{19}$$

This proves that the total relativistic mass is equal to the experimental value. Also,

$$m_1 + m_3 = 937.3\,MeV = m_n - 2.26\,MeV/c^2$$

$$m_2 + E_H/c^2 = 938.27\,MeV/c^2 = m_p$$

with $m_n = 939.56\,MeV/c^2$ mass of the neutron.
That fully explains the so-called mass deficit of the deuteron. We return on this in Sec. 6.

With regards to the magnetic moment of the deuteron, which is a vector quantity, we assume that the direction is perpendicular to planes Π_1 and Π_2, and since these planes form an angle ψ with the deuteron plane Π_d, we further assume that the magnitude of $\overline{\mu}_d$ is given by

$$\mu_d = \mu_p + \mu_n + \left[-\left(\frac{qV_1R_1}{2}\right) + \frac{qV_2R_2}{2} + \frac{qV_3R_3}{2}\sin\psi \right] \tag{20}$$

where

$$\psi = \frac{\pi}{6} = 0.5236 = 30^0\,; \qquad \sin\psi = 0.5$$

$$\mu_p = 2.7928\frac{q\hbar}{2m_p}\,; \quad \mu_n = -1.913\frac{q\hbar}{2m_p}\,. \tag{21}$$

As

$$\frac{qV_1R_1}{2} = 0.0334\,\frac{q\hbar}{2m_p} \tag{22}$$

$$\frac{qV_2R_2}{2} = 0.00979\,\frac{q\hbar}{2m_p} \tag{23}$$

$$\frac{qV_3R_3}{2} = 3.45\cdot 10^{-4}\,\frac{q\hbar}{2m_p} \tag{24}$$

we find

$$\mu_d = \frac{(2.7928 - 1.913) - 0.0236 + 3.45\cdot 10^{-4}\sin\psi}{2m_p} q\hbar \tag{25}$$

Above equations give

$$\mu_d = \frac{0.8798 - 0.0236 + 3.45\cdot 10^{-4}\times 0.5}{2m_p} q\hbar = 0.85637\frac{q\hbar}{2m_p} \tag{26}$$

in accordance with the experimental value.

The quantity within brackets in eq. (20) represents the dynamical contribution to the deuteron's magnetic moment owing to the rotation of the three point-form particles that form the deuteron in plane Π_d. The direction of $\overline{\mu}_d$ is the famous z direction of particle physics.

We shall subsequently prove that the spin of the deuteron in the direction z is $\hbar$, provided that the direction of the electron spin, as well as that of the electron's magnetic moment, is z (figure 6).

3 The meaning of the electromagnetic energy (binding energy)

Any proton is formed by three rotating particles (with charges $2q/3$, $-q/3$, $2q/3$) and hence generates a magnetic field [21,22]. (The three fields are re-

sponsible for the well-known magnetic moment of the proton and for quantization of the electron orbits in hydrogen). In particular, the two protons of the deuteron give rise to two magnetic fields H_1 and H_2 which, owing to the structure of the model are "rotating" fields. So, they induce an electromotive force on the electron and the related electromagnetic energy is:

$$E_H = E_{H_1} + E_{H_2} \tag{27}$$

$$E_{H_1} = (\mu_0 H_1) \cdot \frac{qV_1 R_3}{2} \; ; \qquad E_{H_2} = (\mu_0 H_2) \cdot \frac{qV_2 R_3}{2} \tag{28}$$

μ_0 magnetic permeability in vacuum, with

$$H_1 = \frac{[(2q/3)\, v_1 r_1 - (q/3)\, v_2 r_2 + (2q/3)\, v_3 r_3]}{4\pi (R_1 - R_3)^3} \times f(\psi) \tag{29}$$

$$H_2 = \frac{[(2q/3)\, v_1 r_1 - (q/3)\, v_2 r_2 + (2q/3)\, v_3 r_3]}{4\pi (R_2 - R_3)^3} \times f(\psi) \tag{30}$$

where, for each proton, r_1, r_2 and r_3 are the distances of the three constituent particles from the center of mass of the proton while v_1, v_2 and v_3 are the rotation speeds of such particles (see figure 2(b)). Also ψ is the angle formed by each of the two protons planes with the plane of the deuteron Π_d and according to preceding assumptions $\psi = 30^o$ (figure 5). The numerical values of the aforesaid quantities are reported in a study by Di Caprio about the dynamical structure of the proton [21]

$$r_1 = 1.399 \cdot 10^{-15} m\,; \quad r_2 = 1.3788 \cdot 10^{-15} m\,; \quad r_3 = 1.4 \cdot 10^{-15} m \tag{31}$$

$$v_1 = 0.95775\; c\,; \qquad v_2 = 0.94477\; c\,; \qquad v_3 = 0.9599\; c\,. \tag{32}$$

The form of function $f(\psi)$ can be deducted from the numerical analysis of the general results on electro-magnetism illustrated by Arenhövel in [41,42]

$$f(\psi) = \left[1 + \tan\left(\frac{\pi}{2} - \psi\right)\right] \cdot \left[\tan\left(\frac{\psi}{2}\right)\right]^{32/9} . \tag{33}$$

Inserting $\psi = \pi/6$ we find the numerical value $f(\psi) = 0.025$. With the above values (and with R_1, R_2, R_3, V_1, V_2, V_3 as given by (12), (13))

$$E_{H_1} = 5.4664 \cdot 10^{-12} J = 34.12\, MeV \tag{34}$$

$$E_{H_2} = 25.4 \cdot 10^{-12} J = 158.93\, MeV \tag{35}$$

$$E_H = E_{H_1} + E_{H_2} = 193\, MeV \tag{36}$$

in accordance with (17).
We claim that E_H is but the binding energy E_B, namely

$$E_B = E_H = 193\, MeV. \tag{37}$$

As a matter of fact, setting

$$g_d = \frac{1}{\alpha} \frac{E_B}{m_d c^2} \tag{38}$$

where α is the *fine structure constant* we find

$$g_d = 137 \cdot \frac{193\, MeV}{1875.57\, MeV} = 14.1 \sim 14\,. \tag{39}$$

So, g_d is the experimental value of the *strong interaction constant*. In second place, $193\, MeV$ is the experimental value of a resonance energy for photodisintegration of the deuteron [13].

4 The spin and the electric charge

The deuteron spin is $s_d = \hbar$. In our model the spin is the sum of three contributions owing to the spins of three particles (two protons and an electron). Furthermore, the spin is a vectorial quantity. Considering the direction z identified by the perpendicular to the plane of motion of the three pointform particles we find that the spin of the deuteron in the direction z is given by (see figure 6)

$$spin\, d\, (in\, the\, direction\ z) = spin\, p_1 \cdot \sin\psi + spin\, p_2 \cdot \sin\psi + electron\, spin$$

with $\psi = \pi/6$. Therefore,

$$spin\, d\, (in\, the\, direction\ z) = \frac{\hbar}{2}\sin\frac{\pi}{6} + \frac{\hbar}{2}\sin\frac{\pi}{6} + \frac{\hbar}{2} = \frac{\hbar}{4} + \frac{\hbar}{4} + \frac{\hbar}{2} = \hbar\,.$$

This sum equals $\hbar$ in agreement with the experimental value.
As regards the electric charge we have

$$charge\ of\ deuteron = q + q - q = q$$

which is o.k.

5 Check of the conditions of equilibrium

For each particle the orbit is circular with radius R. Hence, R satisfies the equations

$$R = const\,; \qquad \dot{R} = 0\,; \qquad \ddot{R} = 0 \tag{40}$$

which implicates that the sum of the forces acting on the particle equals zero. In particular the centrifugal (inertial) force is balanced by the sum of the electromagnetic (active) forces, which are Coulomb and Lorentz forces. Since the orbits are circles and the rotation speeds are constant, all these forces are constant (along the orbit). Consequently, the aforesaid balance identifies a *condition of dynamical Equilibrium.* In order to explicitly point this out, we decompose the system into three two-body subsystems, for each of which we set into evidence a *reduced mass.*
Consider, e.g. proton p_1. The condition of equilibrium along orbit 1, is

$$\frac{\gamma_1 m_p^* V_1^2}{R_1} = \frac{kq^2}{(R_1 + R_3)^2} - \frac{kq^2}{(R_1 + R_2)^2} + F_L \tag{41}$$

where

$$\begin{aligned} m_p^* &= \left[m_p \cdot m_p \frac{R_1}{R_1 + R_2} \Big/ \left(m_p + m_p \frac{R_1}{R_1 + R_2}\right)\right] \\ &\quad - \left[m_p \cdot m_0 \frac{R_1 + R_2}{R_3} \Big/ \left(m_p + m_0 \frac{R_1 + R_2}{R_3}\right)\right] \\ &= 361.37\, MeV/c^2 \end{aligned} \tag{42}$$

$$\gamma_1 V_1^2 = c^2 \tag{43}$$

$$F_L = F_{L_1} + F_{L_2} + F_{L_3} \tag{44}$$

$$F_{L_1} = 0\,; \qquad F_{L_2} = B_2\, qV_1\,; \qquad F_{L_3} = B_3\, qV_1 \tag{45}$$

$$\begin{aligned} B_2 &= \mu_0 \times \frac{qV_2R_2}{4\pi(R_1-R_2)^3} = \mu_0 \cdot q \times \frac{0.4244 \cdot c \times 4.835 \cdot 10^{-18}m}{4\pi\left[(8.955-4.835)\cdot 10^{-18}m\right]^3} \\ &= \left[\mu_0 \times 1.121 \cdot 10^{23}\right] \frac{Weber}{m^2} \\ B_3 &= \mu_0 \times \frac{-qV_3R_3}{4\pi\left(R_1-R_3\right)^3} = -\mu_0 \cdot q \times \frac{0.0803 \cdot c \times 0.915 \cdot 10^{-18}m}{4\pi\left[(8.955-0.915)\cdot 10^{-18}m\right]^3} \\ &= \left[\mu_0 \times \left(-5.4 \cdot 10^{20}\right)\right] \frac{Weber}{m^2}. \end{aligned}$$

The above equations implicate that the sum of the forces of Lorentz on proton p_1 is equal to

$$\begin{aligned} F_{L_1} + F_{L_2} + F_{L_3} &= \left[1.121 \cdot 10^{23} - 5.4 \cdot 10^{20}\right](\mu_0 q V_1) \\ &= \left\{\left[1.1156 \cdot 10^{23}\right] \times \mu_0 q V_1\right\} Newton. \end{aligned} \tag{46}$$

It follows from (46) and (12), (13) that

$$(F_{L_1} + F_{L_2} + F_{L_3}) \times R_1 = 296\, MeV. \tag{47}$$

On the other hand, eq. (41) is equivalent to

$$\begin{aligned} \gamma_1 m_p^* V_1^2 &= \frac{kq^2}{R_1+R_3} \cdot \frac{R_1}{R_1+R_3} - \frac{kq^2}{R_1+R_2} \cdot \frac{R_1}{R_1+R_2} \\ &\quad +(F_{L_1} + F_{L_2} + F_{L_3}) \cdot R_1 \end{aligned} \tag{48}$$

with

$$\gamma_1 m_p^* V_1^2 = m_p^* \cdot c^2 = 361.37\, MeV \tag{49}$$

$$\frac{kq^2}{R_1+R_3} \cdot \frac{R_1}{R_1+R_3} = 145.9\, MeV \times 0.9073 = 132.37\, MeV \tag{50}$$

$$\frac{kq^2}{R_1+R_2} \cdot \frac{R_1}{R_1+R_2} = 104.46\, MeV \times 0.649 = 67.83\, MeV. \tag{51}$$

We infer from (47), (50) and (51) that

$$\begin{aligned} r.h.s.\ of\ eq.\ (48) &= 132.37\,MeV - 67.83\,MeV + 296\,MeV \\ &\cong 361\,MeV. \end{aligned} \tag{52}$$

In parallel, because of (49)

$$l.h.s.\ of\ eq.\ (48) \cong 361\,MeV. \tag{53}$$

Equations (52) and (53) implicate that eq. (48) is satisfied: then eq. (41) is satisfied as well.

This completes our reasoning regarding particle p_1: this particle is in *dynamical Equilibrium.* In a similar way, one shows that particle p_2 and particle e are in *dynamical Equilibrium.*

The above demonstration illustrates the nature of the nuclear force: *such force is the combined effect of Coulomb and Lorentz forces plus the centrifugal force* (*inertial force*).

6 Photo - decomposition of the deuteron

The proposed model gives a satisfactory explanation for the observed decompositions of the deuteron after hitting it with energized particles (e.g. photons, see (1)). The binding energy has been identified as $E_B = 193\,MeV$ and experiments show a resonance (more precisely, a minimum of the cross section (see figure 7)) at this energy level: that indicates a fundamental way of disintegration of the deuteron. By going into further depth in this issue we can show that said disintegration is correlated to the bearing of an energized proton and of a particle η (plus a triple neutrino). Moreover, the energized proton triggers a chain reaction that involves a second deuteron nucleus and so on. Further ways of decomposition refer to *static resonances* among which the noted one at $2.26\,MeV$ and others leading to the generation of a pion or of particles Δ, ρ, N, η'.

6.1 The first dynamic resonance (decomposition of type energized proton $+\eta$)

Hitting at a deuteron nucleus with a photon carrying energy $193\,MeV$ (equal to the binding energy) we decompose the proton into an energized proton and a contracted neutron which decays into a particle η and a neutrino. The η particle is unstable and eventually decays in pions according to noted experimental laws.
The following reaction is brought into evidence:

$$\begin{aligned} d + 193\,MeV &= (\gamma_1 p_1) + n_c + 2e^- + 2e^+ + 2\nu_\mu \\ &\rightarrow (\gamma_1 p_1) + (\eta + \nu_\mu) + 2\nu_\mu + 2e^+ + 2e^- \end{aligned} \tag{54}$$

with

$$(\gamma_1 p_1) = 1.618 \times 938.27\,MeV = 1518.12\,MeV \tag{55}$$

$$n_c \quad \textit{contracted neutron with mass } 547.69\,MeV \tag{56}$$

$$\eta \quad \textit{particle with mass } 547.45\,MeV;\ \textit{spin } 0;\ \textit{charge } 0 \tag{57}$$

$$\nu_e \quad \textit{electronic neutrino};\ \textit{mass } 5\,eV;\ \textit{spin } \hbar/2 \tag{58}$$

$$\nu_\mu \quad \textit{muonic neutrino};\ \textit{mass } 0.24\,MeV;\ \textit{spin } \hbar/2. \tag{59}$$

By *contracted neutron* we mean a composite particle formed by an electron in revolution around a proton, at a distance conveniently smaller than that in the standard neutron. Consequently, the relativistic mass of said particle is smaller than m_n and equal to $547.45\,MeV$ (while the spin and the electric charge are respectively equal to $\hbar/2$ and to zero as in the standard neutron). The following relations turn out verified:

$$E_{pe} = -\frac{kq^2}{r_{pe}} = -\frac{391.6}{3}\,MeV \tag{60}$$

with

$$r_{pe} = (R_2 - R_3) \cdot \frac{3}{1 + 2\,(R_3/R_2)^2}$$

and the total relativistic mass of n_c is

$$\begin{aligned} mass\,of\ \ n_c &= \left(m_p + \frac{E_{pe}}{c^2}\right) + \gamma_{pe}\left(m_0 + \frac{E_{pe}}{c^2}\right) \\ &= (m_p + \gamma_{pe} m_0) + (1 + \gamma_{pe})\,\frac{E_{pe}}{c^2} \end{aligned} \tag{61}$$

with $\gamma_{pe} = 2$. Then,

$$mass\,of\ \ n_c = m_p + 2m_0 + 3\frac{E_{pe}}{c^2} = 547.69\,MeV. \tag{62}$$

At one time the spin of n_c is equal to $\hbar/2$. In fact,

$$\begin{aligned} spin\ of\ \ n_c &= spin\ p_2 + spin\ e\,(cos\,90^0) \\ &= (\hbar/2) + (-\hbar/2) \times 0 = \hbar/2 \end{aligned} \tag{63}$$

$$v_{pe} = 0.999 \cdot c\,.$$

It follows from (61), (62) that

$$spin\ of\ \ n_c = \frac{\hbar}{2}\,. \tag{64}$$

As $\gamma_{pe} = 265 > 1.618$ particle n_c is unstable and decays in

$$n_c \to \eta + \nu_e\,. \tag{65}$$

Particle η in turn decays according to noted experimental laws.

6.2 Chain nuclear reaction

The energized proton $(\gamma_1 p_1)$ has a kinetic energy about three times the binding energy of the deuteron. Infact,

$$T_1 = (\gamma_1 - 1)\,m_p \cdot c^2 = 0.618 \times 938.27\,MeV = 579.97\,MeV \tag{66}$$

while

$$3 \cdot E_B = 3 \times 193\,MeV = 579\,MeV. \tag{67}$$

Consequently,

$$T_1 \sim 3 \cdot E_B \,. \tag{68}$$

That means that after disintegrating a deuteron by hitting it with a photon of energy $193\,MeV$ we get an energized proton (plus a particle η and a particle ν_e) which in turn can break three more deuterons, and so on. The reaction is divergent and then, in this manner, we can produce clean nuclear energy, provided we control the reaction. The control can be eventually achieved with the use of cadmium bars the purpose of which is simply to intercept part of the energized proton (not to moderate neutrons, since this is not the philosophy of our fission procedure; it is clear that we are dealing with fission, not with fusion). The following example illustrates a controlled chain reaction in two stages.
STAGE 1: fission of a first nucleus according to

$$193\ MeV + d_1 = 2068.6\,MeV \rightarrow 1.618\,m_p + \eta + 3e^+ + 3e^-$$

$$\eta = 547.5\,MeV$$

$$1.618\,m_p + \eta \rightarrow p + \eta + 0.618\,m_p = p + \eta + 578.86\,MeV.$$

STAGE 2: fission of a second nucleus, according to

$$578.86\,MeV + d_2 = 2455.45\,MeV \rightarrow \Omega^- + 2e^+ + 193\,MeV$$

$$\Omega^- = 2261 MeV.$$

SUBSEQUENT Decay

$$\Omega^- = N_{1530} + K^- + 236\,MeV$$

Released energy $236\,MeV$.

6.3 Static resonances

6.3.1 Energy level 2.26 *MeV*. Decomposition (n, p) or (p, ρ, π^0, ν_e)

$$\begin{aligned} m_D c^2 + 2.26\,MeV &= (937.3 + 2.26)\,MeV + 938.27\,MeV \\ &= (m_n + m_p)\,c^2 \end{aligned} \tag{69}$$

where

$$\begin{aligned} 937.3\,MeV &= m_1c^2 + m_3c^2 \\ 938.27\,MeV &= m_2c^2 + E_H \end{aligned}$$

$$D + 2.26\,MeV = n + p = 939.56\,MeV + 938.27\,MeV. \tag{70}$$

Alternatively, as

$$\begin{aligned} 939.56\,MeV &= \rho + \pi_0 + E_{H_1} \\ &= 770\,MeV + 134.976\,MeV + 34.5\,MeV \end{aligned} \tag{71}$$

then

$$n \rightarrow \rho + \pi^0 + photon + \overline{\nu}_e \tag{72}$$

and

$$D + 2.26\,MeV \rightarrow p + \rho + \pi^0 + \overline{\nu}_e + photon \tag{73}$$

with $\overline{\nu}_e$ electronic anti-neutrino.
The photon has energy $34.5\,MeV$, equal to the electromagnetic energy that couples electron and proton p_1 in the deuteron.

6.3.2 Energy level 138.4 *MeV*. Decomposition $(p, \rho, \pi^0, \pi^0, \overline{\nu}_\tau)$

The sum of the Coulomb energy E_{12} that couples particle one (proton p_1) to particle two (proton p_2) and of the electromagnetic energy E_{H_1} that couples particle two to particle three (the electron) is

$$\Delta E_{123} = E_{12} + E_{H_1} = 104.52\,MeV + 33.9\,MeV = 138.4\,MeV. \tag{74}$$

Then

$$\begin{aligned} \Delta E_{123} + m_dc^2 &= 2014.52\,MeV \\ &= (938.27 + 770.68 + 2 \times 134.976 + 34.9 + 1.798)\,MeV \\ &= p + \rho + \pi^0 + \pi^0 + photon + \overline{\nu}_\tau \end{aligned} \tag{75}$$

with $\overline{\nu}_\tau$ tauonic anti-neutrino, photon with energy $34.5\,MeV$.

6.3.3 Energy level 294.94 *MeV*. Decomposition (Δ, ρ, π^0, ν_e)

Note that the Coulomb energy $E_{13} = -146.34\,MeV$ contributes to both m_1 and m_3. By administering to deuteron an energy $E = 2\,|E_{13}| = 292.68\,MeV$ we provoke the disjointing of particle one from particle three and, thereafter the separation of particle one from the remaining two. It is

$$\begin{aligned} d + 292.64\,MeV &= 1875.56 + 292.6\,MeV \\ &= (938.27 + 292.64)\ MeV + 937.3\,MeV \\ &= 1230.95\,MeV + 937.3\,MeV. \end{aligned} \tag{76}$$

As 1230.95 is the mass of particle Δ, and such particle has charge and spin respectively equal to the charge and to the spin of the proton, we have

$$d + 292.68\,MeV = \Delta + 937.3\,MeV \tag{77}$$

which relation is the correspondent of

$$d = p + 937.3\,MeV.$$

Consequently,

$$d + (292.68 + 2.26)\ MeV = \Delta + 939.56 = \Delta + n \tag{78}$$

namely

$$d + 294.94\,MeV = \Delta + n \tag{79}$$

and, as in case 6.3.1

$$n \rightarrow \rho + \pi^0 + E_{H_1} + \overline{\nu}_e = \rho + \pi^0 + photon + \overline{\nu}_e\,.$$

All in all,

$$d + 294.94\,MeV \rightarrow \Delta + \rho + \pi^0 + \overline{\nu}_e + photon \tag{80}$$

The photon has energy $34.5\,MeV$ equal to E_{H_1}.

6.3.4 Energy level 513 *MeV*

It is

$$E_{13} + E_{23} = -513\,MeV$$
$$|E_{13} + E_{23}| = 513\,MeV$$
$$d + 513\,MeV = 938.27\,MeV + 1450.5\,MeV = p + N \tag{81}$$

with N designating a barion with charge 0, spin $\hbar/2$, mass $1450.5\,MeV$. Particle N eventually decays according to

$$N \to \rho + 3\pi^0 + \pi^- + \pi^+ + \overline{\nu}_e\,. \tag{82}$$

In fact,

$$1450.5 = 771 + 3 \times 134.976 + 2 \times 139.56\,. \tag{83}$$

6.3.5 Energy level 706 *MeV* (decomposition (p, N_{1650}) or decomposition of type η')

It is

$$\{|E_{13}| + |E_{23}|\} + E_H = (513 + 193)\ MeV = 706\,MeV. \tag{84}$$

We find

$$d + 706\,MeV = 938.27\,MeV + 1643\,MeV = p + N_{1650}\,. \tag{85}$$

Note that the most probable value of mass of particle N_{1650} is precisely $1643\,MeV$. Also,

$$d + 706\,MeV \to p + \eta' + 3\pi^0 + \pi^+ + \pi^- + \overline{\nu}_e \tag{86}$$

with

$$\eta' = 959.8\,MeV\,;\quad charge\,0\,;\quad spin\,0\,. \tag{87}$$

Particle η' is a noted particle of experimental physics and the static resonance at about $700\,MeV$ is pointed out in [13]. Further note,

$$\begin{aligned} mass\ of\ \eta' &\sim mass\ of\ \rho + 193\,MeV \\ &= mass\ of\ \rho + E_H \\ &= mass\ of\ \rho + E_B \end{aligned} \tag{88}$$

with E_B the "binding energy" of the deuteron.

The above relationships point out a more than satisfactory agreement with the experiments.

7 The center of mass

The following eq. proves that the geometric center of the deuteron (point O) is the center of mass:

$$m_1 (r_2 - r_3) = m_{23} \cdot r_1 + \frac{E_H}{c^2} (r_2 - r_3 \cos\psi) \tag{89}$$

with

$$m_{23} = \frac{m_2 r_2 + m_3 r_3}{r_2 + r_3}. \tag{90}$$

We can check that eq. (89) turns out satisfied. In fact it is

$$\begin{aligned} m_1 &= 1.618 \times 896.836\ MeV/c^2 = 1451.07\, MeV/c^2 \\ m_2 &= 1.1044 \times 675.39\ MeV/c^2 = 745.9\, MeV/c^2 \\ m_3 &= 1.0032 \times (-512.79)\, MeV/c^2 = -514.38\ MeV/c^2 \end{aligned}$$

and then

$$\begin{aligned} m_{23} &= \frac{745.9 \times 4.835 - 514.38 \times 0.915}{4.835 + 0.915} MeV/c^2 \qquad (91) \\ &= 545.35\ MeV/c^2 \\ m_1 (r_2 - r_3) &= 1451.07 \times 3.92 \cdot 10^{-18} \left(MeV/c^2\right) \times m \qquad (92) \\ &= 5688 \cdot 10^{-18} \left(MeV/c^2\right) \times m \\ m_{23} \cdot r_1 &= 545.35 \times 8.955 \cdot 10^{-18} \left(MeV/c^2\right) \times m \qquad (93) \\ &= 4883.6 \cdot 10^{-18} \left(MeV/c^2\right) \times m \\ \frac{E_H}{c^2} (r_2 - r_3 \cos\psi) &= 193\ MeV/c^2 \times 4.17 \cdot 10^{-18} m \\ &= 805.47 \cdot 10^{-18} \left(MeV/c^2\right) \times m\,. \end{aligned}$$

It follows from the above equations that

$$\begin{aligned} m_{23} \cdot r_1 + \frac{E_H}{c^2}(r_2 - r_3 \cos\psi) &= (4883.6 + 805.47) \cdot 10^{-18}(MeV/c^2) \times m \\ &= 5688 \cdot 10^{-18}\left(MeV/c^2\right) \times m\,. \end{aligned} \tag{94}$$

Equations (92) and (94) bring about that eq. (89) is satisfied.

8 Inexistence of a radiation problem

Since each of the three particles rotates at a constant speed, the corresponding acceleration is equal to zero. This implicates that none radiates energy.

9 Mathematical and physical significance of the proposed dynamic model

9.1 Mathematical significance

The "solution of the deuteron problem" has been taken back to the solution of a system of 11 equations in 7 unknowns. The equations represent as many conditions, namely: 1) the mass condition; 2) the magnetic moment condition; 3) the spin condition; 4) and 5) the synchrony conditions; 6) the "strong interaction" condition; 7) the condition of stability; 8), 9) and 10) the three conditions of dynamical equilibrium (one for each rotating particle); 11) the "center of mass" condition. The unknowns are: three radii, three rotation speeds and the angle ψ. The equations are non-linear and include relativistic contributions (both in the sense of SR and in accordance with our principle of equivalence Potential energy/mass). It is clear that there may be no existing solution at all. On the contrary, we have shown the existence of a solution that is physically significant and, to this end, we have only used the 7 conditions. Afterwards, we ascertained that the remaining conditions are automatically verified. So, from the mathematical point of view, the problem is very well posed and solved.

9.2 Physical significance

The basic physical properties of the deuteron, as well as the observed modes of decomposition (by hitting the deuteron with energized photons) have been fully described. Unlike the SM, our model does not suffer from problems of mass deficit or magnetic moment deficit, nor from undetermination regarding the stability of the structure. Moreover, it avoids the mistake of identifying the binding energy with the energy-mass deficit, which is small and negative (i.e. $-2.26\,MeV$). On the contrary, the binding energy is *positive* and much larger (i.e. $193\,MeV$) and, also, such a quantity contributes to both the mass and the strong interaction constant (i.e. 14). The binding energy is the electromagnetic energy acquired by the electron owing to the rotation in the magnetic fields generated by the two protons. The nature of the nuclear force has been established once and for all: the force is electromagnetic and, at any time, is balanced by the inertial force (*centrifugal force*). For each constituent particle there exists a condition of *dynamical Equilibrium* so that the orbits are circles and the rotation speeds are constant. In principle, the nuclear force is not constant, except in Equilibrium. Stability assures that following small external disturbances the deuteron keeps its dynamical Equilibrium and the nuclear force returns to a constant value. Things are different vs. large disturbances that determine abrupt instability. This is the case when one considers an energy injection equal to the binding energy (i.e. $193\,MeV$). Then the deuteron disintegrates itself and is transformed into an energized proton, with kinetic energy $580\,MeV$, plus a particle η (plus a neutrino). As the kinetic energy is about 3 times the breaking energy we can, in principle, trigger a nuclear chain reaction with gain factor 3.

The reaction has nothing to do with fusion nor with classic fission of heavy elements (by the use of moderating neutrons). The control of the reaction is essentially leadable to the seizure of part of the energized protons. Regarding the energy balance, we have clearly explained where the generated nuclear energy comes from: the energized proton p_1 draws energy from the ensemble of the two remaining particles (proton p_2 and the electron e), considered altogether with their mutual electrical coupling. More precisely, in a first stage of the transition the electron rotates round p_2 at

a distance of the order $7 \cdot 10^{-16}m$ so that the two particles constitute a "contracted" neutron with mass $547MeV$ only. The "contracted neutron" eventually decays in η plus ν_e and, afterwards, in pions.

Furthermore we have pointed out various ways of decomposition at convenient excitation energies; in particular those leading to the bearing of particles ρ, Δ, π, N, η'. For each of them we have indicated accurate values, more reliable than the experimental ones.

We stress the fact that our results have been derived from relativistic equations that include both Kinetic energy/mass equivalence and Potential enrgy/mass equivalence. The mass and the spin were determined as follows: the binding energy has been computed from noted equations of the magnetic field of the proton [21,22] which are derived from a relativistic three-quark model.

Other qualifying points are: 1) for each constituent particle the electromagnetic force (nuclear force) is balanced by the inertial force (centrifugal force); 2) the geometric center of the deuteron coincides with the center of mass.

10 Preventive answer to standard or foreseeable objections

From direct contact with experts of classical nuclear energy generation and from a thorough discussion with international Patent Offices, like e.g. those in the U.S.A., Russia and Western Europe, some crucial points have come into evidence. We shell try to list and respond to the main objections.

(1) Rotating particles should radiate and then their motion should be unstable. Completely false and totally mistaken! (Please refer to the concise explanation in Sec. 8). Existing theories regarding particle radiation completely ignore the fundamental role of the *centrifugal force*, which stabilizes the motion. Such force can be found in Newton's gravitation law as well, but has not been recognized as such so far. Eq. (41) gives a plastic illustration of the essential importance of centrifugal force in the existence of a dynamical equilibrium for the

deuteron. Other crucial examples we can mention are electrodynamical quantization and gravitational quantization [22,41,42].

(2) The binding energy E_B should be negative and equal to the energy (mass) deficit $-2.26\,MeV$. This is postulated by the SM. We have shown that, to the contrary, the binding energy is positive and equal to $193\,MeV$. This finding is consistent with the experimental results illustrated in the book *Photodisintegration of the deuteron - A review of theory and experiment*, by H. Arenhövel and M. Sanzone [13]. Moreover, we have provided a satisfactory theoretical explanation of all of the experiments described in that book. We have also seen that the value of the strong interaction constant (i.e. $g_d \sim 14$) is directly bonded to the aforesaid value of the binding energy.

(3) The new theory is totally different from the standard accepted by the international scientific community. True, more than true! But this is not at all an argument, considering the more than serious deficiences and mistakes of the SM, which is not even able to explain mass deficit and magnetic moment deficit! It is perhaps not superfluous to note that the theory proposed by Arenhövel and Sanzone in the book quoted above, is in turn in contrast with the SM and is probably not generally accepted by the international community at large. Note that we go well beyond that book, as we use dynamic and relativistic equations, furthermore, providing a unifying vision of the more general problem of the structure of light nuclei.

(4) The sum of the the spins of the two protons and of the electron equals $(1/2)+(1/2)-(1/2)=1/2$, whilst the deuteron has spin 1. How can this contradiction be explained? The answer is that we account for a three-dimensional model in which the vectorial composition of the spin equals 1 precisely. This is shown in Sec. 4.

(5) By disintegrating the deuteron at a convenient level of excitation we can trigger a chain reaction. How is this possible? Where does the energy gain come from? The answer is as follows. Hitting the deuteron with a photon having an energy of $193\,MeV$ (i.e. the binding energy) we decompose the deuteron into an energized photon with kinetic

energy $580 MeV$ (i.e. about three times the binding energy) plus a "contracted" neutron (formed by the remaining proton and the electron), which decays into an η particle plus one neutrino. The energy balance is

$$m_d \cdot c^2 + 193\, MeV = 1.618\, m_p \cdot c^2 + 547.45\, MeV$$

i.e.

$$1875.57\, MeV + 193\, MeV = 1.618 \times 937.28\, MeV + 547.45\, MeV$$

with $547.45\, MeV$ equal to the mass of particle η and with 1.618 the *golden ratio.* The above balance is associated with the following decomposition

$$d + 193\, MeV \rightarrow 1.618\, m_p + \eta + \nu_e$$

with ν_e electronic neutrino. The *golden ratio* identifies the numerical value of the relativistic mass coefficient γ_1 of proton p_1. The kinetic energy of the emitted proton is then

$$T = (\gamma_1 - 1) \cdot m_p \cdot c^2 = 0.618 \times 938.27 \approx 579.9\, MeV$$

As $579,9\, MeV \approx 3 \times 193\, MeV = 3\, E_B$ the released energy is about three-times that of the binding energy and is then able to determine the rupture of three more deuterons. This represents the foundation of a chain reaction. The gain factor equals 3. As regards the left particle η, it decays into pions according to noted processes.

(6) The mass of particle η (i.e. $547.45\, MeV$) is smaller than the mass of the standard neutron ($938.56\, MeV$). The difference is determined by the inertial effects of the Coulomb potential energy. Indeed, a standard neutron is formed by an electron in rotation round a proton, at a convenient distance. A "contracted" neutron has a similar structure, but the aforesaid distance is smaller (and thus the mass reduction is larger). The contracted neutron decays in $(\eta + \nu_e)$.

(7) A consolidated technology for photodisintegration of the deuteron exists already. The extension to other light elements (such as e.g. carbon) does not seem an unrealistic objective. However, the mechanism

of the chain reaction is entirely different from the one regarding heavy elements, such as Uranium, and does not give rise to dangerous radiation. Such a mechanism, on the other hand, does not foresee the necessity of slowing down neutrons. We repeat: we are are not proposing the decomposition of an unstable and heavy element into lighter elements (e.g. Ba and Kr) by means of the insertion of slowed down neutrons, but the disintegration of a light and stable element by hitting it with energized protons that carry an amount of energy equal to the binding energy of the nucleus. The process is divergent, i.e. a chain reaction spontaneously arises without the need to "moderate" any intermediate particle. A *control* problem obviously exists in view of "pacific" industrial applications. Cadmium bars could be used to intercept part of the generated flux of protons, but other materials could be effective as well, or even more so.

(8) Our process is strictly based on *fission* and has *nothing to do with fusion*. By virtue of the relatively low temperatures involved, undesirable and accidental fusions can be excluded. The existing technology for generating electric energy using conventional thermal or even nuclear power plants can easily be utilized. Of course, there is no question about the necessity of convenient and conclusive experiments regarding the practical start of the chain reaction.

11 Conclusions

Our theoretical analysis joined with experimental results (in particular see [13]) prove, beyond any reasonable doubt, that the deuteron is formed by three rotating particles, two protons and one electron. The rotations are synchronous and their geometric center coincides with the center of mass. The basic properties of the deuteron are satisfactory reproduced by a three-body relativistic model that marks a substantial advancement with respect to the static two-body standard model (SM) utilized by the international scientific community. We have clearly explained the reasons why the SM fails to indicate correct values for the mass and magnetic moment, and assumes, erroneously, that the binding energy equals the so called mass

deficit (multiplied c^2) which, unfortunately, is negative. We have also seen the inefficacy of the SM in view of explaining the various manners of decomposition of the deuteron by the action of convenient excitation energies. In addition, it does not clarify the nature of the tie between the proton and the neutron nor does it prove the stability of such a tie. On the contrary, we have been able to show the stability of the three-particle model and the fact that the binding energy is *positive* and equal to $193\,MeV$ (against $-2.26\,MeV$). Hitting the deuteron with a photon, carrying this amount of energy, we disintegrate the deuteron and eventually trigger a nuclear chain reaction with a gain factor equal to three. We have also identified all of the other ways of decomposition observed in experiments, so that one now has a unique theoretical frame available to explain MEC (meson exchange) and bearing of particles ρ, Δ, N, η, η'. The core of the study is, however, the demonstration that the nuclear force is an electromagnetic force, counteracted by inertial force. Moreover, the binding energy is the electromagnetic energy acquired by the electron because of its rotation in the magnetic field generated by the two protons. By using these fundamental new notions and, in parallel, adopting relativistic equations, we can easily extend the study to other light nuclei, e.g. carbon.

12 APPENDIX (Stability condition)

The equation

$$\frac{\gamma v^2}{c^2} = 1 \tag{95}$$

determines the rotation speed and the relativistic mass coefficient of proton p_1 in fact as

$$\gamma = \frac{1}{\sqrt{1 - v^2/c^2}}$$

it is

$$\frac{v^2}{c^2} = \frac{\gamma^2 - 1}{\gamma^2}$$

$$\frac{\gamma v^2}{c^2} = \gamma^2 - \gamma$$

so that eq. (95) results in

$$\gamma^2 = \gamma + 1$$

which is the classical equation of the golden ratio, namely the positive solution is

$$\gamma = \gamma_r = \frac{1+\sqrt{5}}{2} = 1.618\,.$$

So

$$\frac{\gamma_r v_r^2}{c^2} = 1$$

and v_r, γ_r identify the rotation speed and the relativistic mass coefficient of particle p_1, in accordance with our general assumptions. Now, we show that condition (95) is sufficient for the stability of the motion of p_1 and consequently for the stability of the remaining two particle p_2 and e, which rotate synchronously with p_1. Consider the numerical relation

$$\begin{aligned} -\frac{E_p}{m_p^* c^2} &= \frac{41.4\,MeV}{361.035} = \frac{1}{8.71855} = \frac{1}{\gamma_r^{4.5}} \equiv \frac{1}{b} \\ \frac{bE_p}{m_p^* c^2} &= 1\,. \end{aligned}$$

Then the following numerical relation turns out satisfied

$$-\frac{b\,E_p}{m_p^* c^2} = \frac{\gamma_r v_r^2}{c^2}$$

and we can write

$$-b\,E_p = \gamma_r\, m_p^*\, v_r^2$$

which represents a condition of Equilibrium. Having stated this, we can point out the following generalization:

$$-b\,E_p = \gamma\, m_p^*\, v^2$$

and since potential energy is equivalent to mass

$$-\frac{b\,E_p}{m_p^*}\left(1 + \frac{bE_p}{m_p^* c^2}\right) = \frac{\gamma\, v^2}{c^2}\left(1 - \frac{\gamma\, v^2}{c^2}\right).$$

The function $f(\gamma)$ defined by

$$f(\gamma) = \frac{\gamma\, v^2}{c^2}\left(1 - \frac{\gamma\, v^2}{c^2}\right) \equiv \frac{\gamma^2 - 1}{\gamma}\left[1 - \frac{\gamma^2 - 1}{\gamma}\right]$$

has a minimum at $\gamma = \gamma_r = 1.618$ (golden ratio).
Therefore, we conclude that the equivalent potential energy defined by

$$\hat{E}_p = b\, E_p \left(1 + \frac{bE_p}{m_p^* c^2}\right)$$

has a minimum along the orbit covered by particle p_1. Moreover, as

$$b\, E_p \left(1 + \frac{bE_p}{m_p^* c^2}\right) \equiv d\left[E_p \left(1 + \frac{E_p}{m_p^* c^2}\right)\right]$$

with d convenient positive constant, we can also say that the equivalent potential energy

$$E_p \left(1 + \frac{E_p}{m_p^* c^2}\right)$$

has a minimum along the orbit covered by p_1 and consequently such orbit is stable.

ACKNOWLEDGEMENTS

Dr. Mario Abram of AIRS (Associazione Italiana per la Ricerca sui Sistemi) gave a precious contribution to the preparation of the article. He carefully reviewed the various equations involved and suggested meaningful corrections. He also took care of the drawings and wrote the final version.

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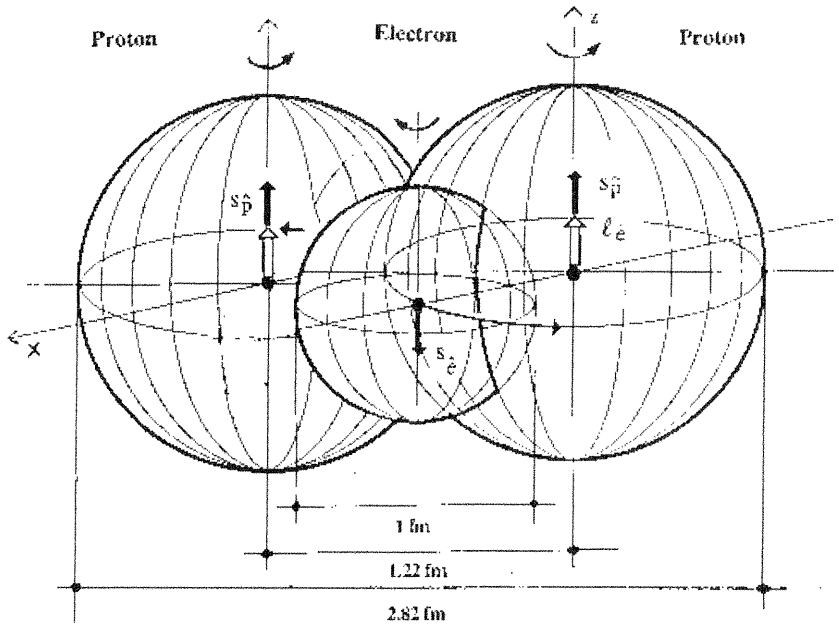
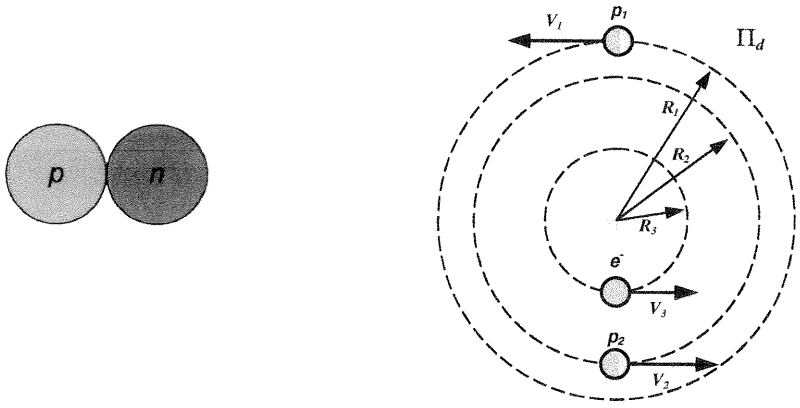


Figure 1. Deuteron structure according to Hadronic Mechanics.

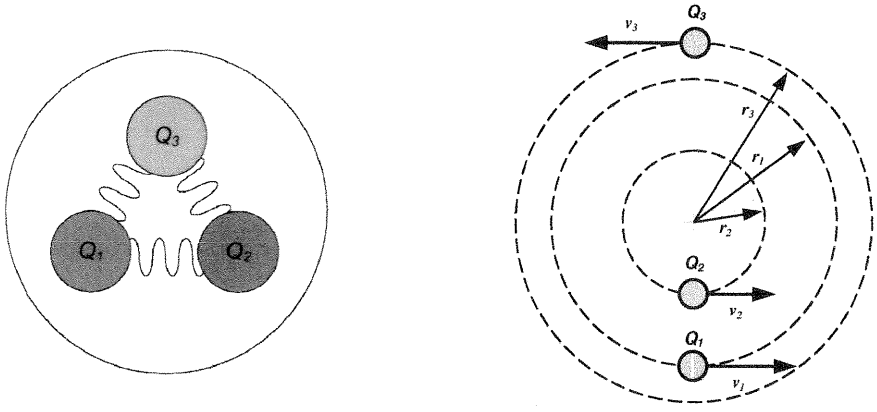


(a) SM model of Deuteron

(b) Dynamic model of Deuteron

p_1 external proton
p_2 internal proton
e^- electron

Figure 2. Deuteron structure.



(a) SM model of the proton

(b) Dynamic model of the proton

Figure 3. Proton structure.

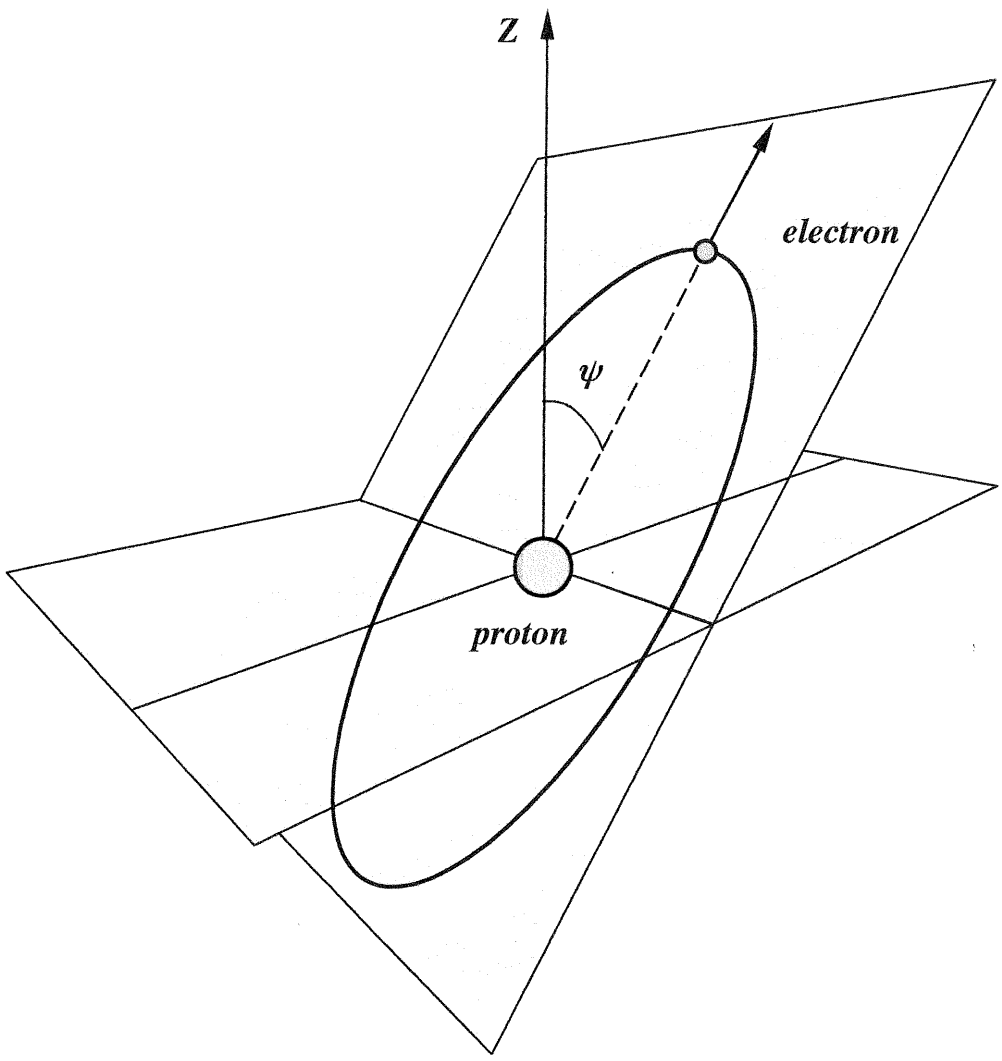


Figure 4. Dynamical structure of the neutron.

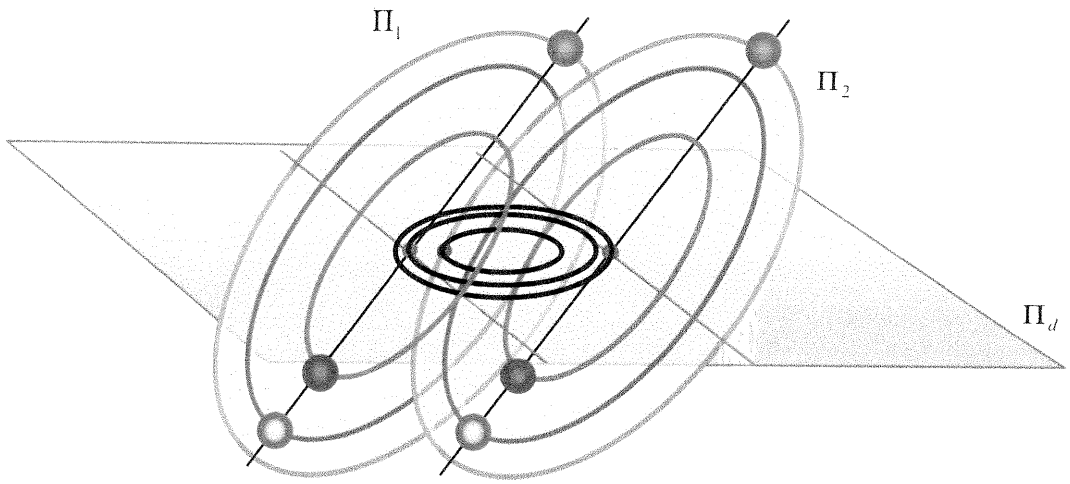
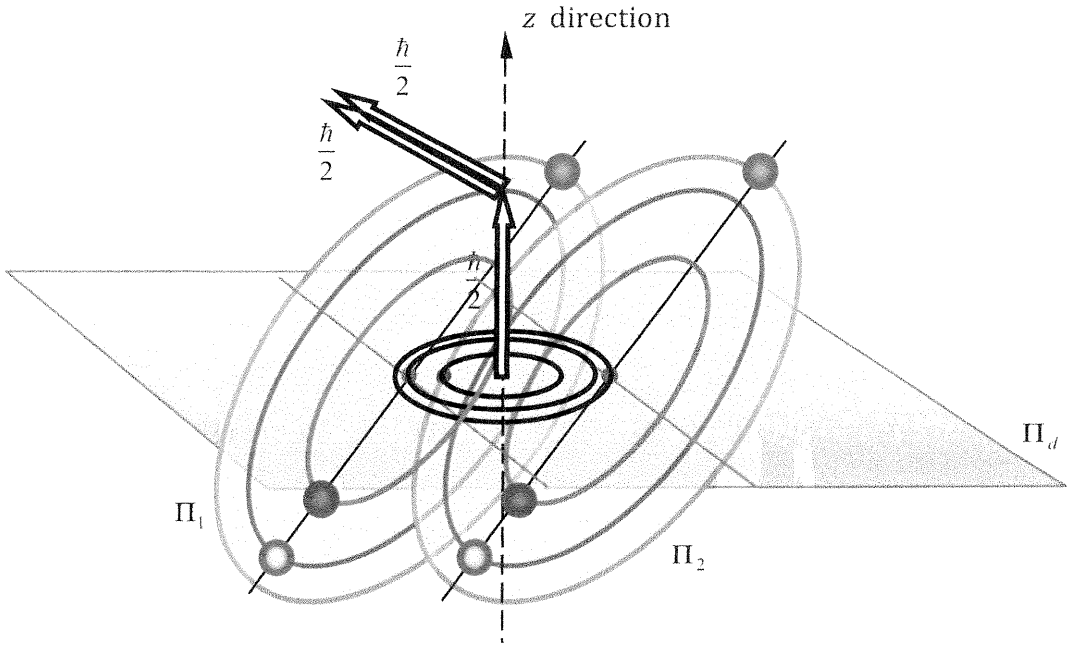


Figure 5. Three dimensional structure of the deuteron.



$$\frac{h}{2}\sin\frac{\pi}{6}+\frac{h}{2}\sin\frac{\pi}{6}+\frac{h}{2}=h$$

Figure 6. Deuteron spin: vectorial composition of the spins of the 3 particles.

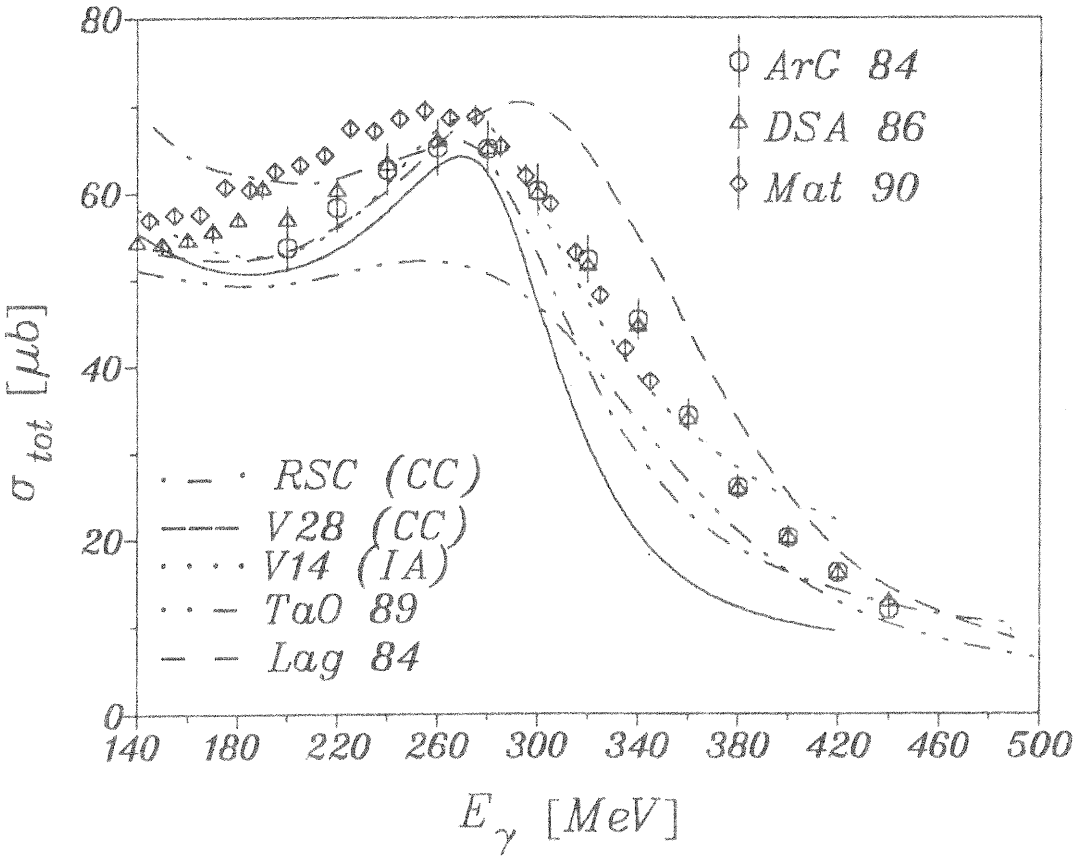


Figure 7. Cross section (from Arenhövel [13], page 106).

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AN OPERATIONAL MECHANISM FEATURING GRAVITY AMPLIFICATION

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Abstract

The least understood property of the physical Universe is non-locality. Beyond the already revealed domain of quantum correlations, non-locality must also be operational in other phenomena. In this way, the presented work tries to interpret Newton's theory of universal gravity. The distinction of the suggested approach with respect to numerous attempts of this kind is that it is not an *ad hoc* phenomenological proposal to accommodate the observed behavior of gravitating objects. Instead, the surmised mechanism is one of the manifestations of Universe's non-locality that transpires through the locality of interactions of the previously considered cellular automaton model. This mechanism exhibits an exclusive paradox of amplification of the impact with the increase of the distance, which stems from having mediation agents in the form of stretching lines rather than restricted corpuscles. Far away from the source this produces an attraction that is inverse-linear with the distance; close to the source a certain lingering reduces the impact of these agents to regular inverse-square behavior. The considered scheme spans over immense galactic effects attributed to "dark matter" and tiny Solar system anomalies. In the cosmological scale, it accounts for flatten galaxy rotation curves and extra rapidity in the galactic clusters. In the astronomical scale, it incorporates small borderline deviations that can be responsible for the precession of planet orbits and unexpected changes of the velocity in space probes; notably, these deviations are of different signs. The non-locality of gravity confronts the concept of general relativity and challenges the existence of gravitational waves.

Keywords: cosmology, gravitation, dark matter, Pioneer's Anomaly, cellular automata

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1. Introduction

The Newton law of gravitation constitutes the basis of the contemporary worldview. Thus, gravitational inconsistencies in distant cosmos detected several decades ago remain the most formidable embarrassment for modern science (see [1,2,3]). The discrepancy between the observed and expected galactic motions reaches up two orders of magnitude. Recently, some minor deviations from standard gravity have been discovered in space explorations: Pioneer's anomaly and flyby maneuvers. These small deviations pale into insignificance by the side of the deficit of gravitational force in the galactic scale, but all these incongruities urge for an explanation.

Basically, three explanations of gravitational abnormalities are considered (see, e.g., correspondingly [3,4,5]): (1) invocation of "dark matter", (2) modification of the rule of dynamics, and (3) alteration of the law of gravitation. Either of these approaches can provide some *ad hoc* remedy to the observed gravitational abnormalities. Most soothing approach to explain the deficit of gravity is to introduce yet unknown non-luminous "dark matter" that could supply the required extra attraction. However, the "dark matter" as a concept raises several objectionable points. The authoritative Standard Model for elementary particles does not mandate its abnormal properties and long-term search has not brought about firm evidences for the existence of hypothetical "dark matter" candidates (see, e.g. [6,7]). Also, strangely enough, "dark matter" always comes in some characteristic shapes of spherically symmetric halos.

A concordance of the observed and expected motions in the galactic scale can be obtained by diminishing the restraining force for small accelerations through modification of the Newtonian dynamics (MOND) (see [4]). Yet this is a purely phenomenological theory specifically designed to fix the particular inconsistency; besides that, employing this mechanism just by itself may not be sufficient [4,8].

A rather consistent way to explain the surprising galactic motions would be to revise the very theory of universal gravity. This approach, however, causes more perturbations in the worldview of physics than taking the usual suspects of elementary particles or introducing a small isolated correction to the rule of dynamics.

This paper sides with the approach of altering the law of gravitation. A novel operational mechanism for the universal gravity is suggested. This mechanism produces a plain inverse-linear dependence of the attraction force on the distance that has been already considered by a number of researches for a possible explanation of the observed gravitational abnormalities. In the cosmological scale, this mathematical dependence leads to flat galactic rotation curves and higher equilibrium velocities in the galactic clusters. In the astronomical scale, the considered mechanism reduces to an approximate inverse-square dependence. Tiny deviations from this approximation can be tested in space exploration experiments with high quantitative precision; a distinctive quality of these deviations is that they are of different signs.

Since the times of Newton there have been undertaken numerous attempts to devise a model that could substantiate the mathematical formalism of gravitation. Exclusively, the developed mechanism does not present an *ad hoc* solution. It naturally comes out from our cellular automaton model of the physical world, namely from its key part that produces Universe's non-locality. This model has been broadly described elsewhere [9-12]. Properties of gravitation in the context of this model are examined in the Appendix.

The main Section 3 analyses the various outcomes of the devised construction. To begin with, the Section 2 concerns the foundations of the phenomenon of gravity: the machinery of the "action-at-the distance" and the origin of inertia.

2. Workings of gravity

2.1 Universe's non-locality and the "action-at-the-distance"

Newton's concept of universal gravitation presupposes action-at-the-distance: any two pieces of matter in the Universe experience instantaneous mutual attraction. If gravitating objects were interacted with a delay their motions would be much more complicated. This would lead, in particular, to aberrational effects, like in the case of light. Because of the absence of such effects Laplace concluded that the speed of gravity should be at least 10^8 times greater than that of light [13].

The confrontation of far-action and local-action is not a profound philosophical question as it may appear. It is common to have a system with two different types of activities developing in two essentially different time scales. So, the "fast" events look like an action-at-the-distance to the "slow" events.

Albert Einstein who introduced a *Gedanken Experiment* with quantum correlations vehemently opposed the possibility of instantaneous interactions since in his view transcending the speed of light is absolutely forbidden. However, the world is not organized this way: the non-locality of the physical Universe in quantum phenomena is a firmly established experimental fact. Likewise, "action-at-the-distance" may seem not acceptable for gravitation. In Einstein's general relativity the impact of gravitation is supposed to be exercised with the speed of light through ripples of the curvature of the spacetime - the conjectural gravitational waves. Yet the persistent non-detection of gravitational waves (see, e.g. [14]) implicates the non-locality as well. This favors the action-at-the-distance alternative in accordance with Newton's concept.

A thorough exposition of the problem of non-locality of the Universe is given in the book [15], where "action-at-the-distance" is portrayed as the pivotal mechanism essentially involved in all physical phenomena. Besides quantum mechanics and gravitation the mechanism of non-locality must be connected to the underlying processes of the physical world, which are necessary for the control of biological organisms (see, in particular, [16]). This connection elucidates a mystifying remark by A. Eddington that "gravitation propagates with the speed of thought".

2.2 Three sides of mass in classical mechanics

Understanding of gravitation is closely related to understanding of the origin of inertia. Reducing inertia to the action-at-the-distance following the Mach principle does not seem satisfactory; it is difficult to imagine that "when the subway jerks, it is the fixed stars that through you down" [15]. In Newtonian concept gravitation is an instantaneous action between pieces of matter, while the force of inertia - resistance to acceleration – comes from the contact with the absolute space. This contact is performed locally, so the force of inertia does not have to travel from one place to another. As summarized in the Appendix, our cellular automaton model produces exactly what is commanded by the Newtonian concept: "slow" material formations, "fast" action-at-the-distance, intrinsic support of uniform motion, and an undetectable absolute frame of reference for the force of inertia. Conventional realizations of this Newtonian concept run into complications.

"Although Newtonian mechanics is the simplest theory that physics has ever constructed, and although for ordinary, medium-sized physical objects Newtonian mechanics is of the highest degree of verification, its logical structure seems to defy all attempts of a complete analysis, if it is assumed that such an analysis presupposes explicit definitions of the fundamental terms involved" [17]. The complications start with the notion of mass. According to Newton's definition, mass is a measure of quantity of matter that is proportional to the density and volume. Many scientists had criticized this definition as an example of circular reasoning. Similarly, circular reasoning appears in attempt to define mass with the Second Law of mechanics using the notion of force. As A.N. Whitehead said: "We obtain our knowledge of forces by having some theory about masses, and our knowledge about masses by having some theory about forces" (see [17]). Despite spectacular achievements in science and technology, "...basic notions of [physics], such as the concept of mass, are entangled with serious uncertainties and perplexing difficulties that have as yet not been resolved" [17]. Perhaps, Newton meant something beyond ordinary thinking. Circular definitions are hidden in any long reasoning; the problem with mass arises because the definition of this most fundamental notion comes out too short, so the unavoidable circularity becomes conspicuous.

The given definition of mass asserts that certain physical effects are proportional to the amount of matter. By adjusting the units of measure it is convenient to get the values of mass for different effects equal rather than proportional. The gravitational mass has two distinct aspects - active and passive, characterizing the source and the recipient parts. To consider them as a single value the law of gravitation employs the gravitational constant G. The universal law of gravitation states: any piece of matter attracts any other piece of matter with a force, F, that is proportional to the product of their masses, M_1 and M_2, and inversely proportional to the square of the distance, R, between them. Thus, a body of mass M_1 is attracted to a body of mass M_2 by a force F_1:

$$F_1 \sim \frac{M_1\,(\text{passive}) \cdot M_2\,(\text{active})}{R^2} \qquad (1)$$

Accordingly, a body of mass M_2 will be attracted to a body of mass M_1 by a force F_2:

$$F_2 \sim \frac{M_2\,(\text{passive}) \cdot M_1\,(\text{active})}{R^2} \qquad (2)$$

The equality of F_1 and F_2 required by the third law of Newton's mechanics implies M_1 (active)/ M_1 (passive) = M_2 (active)/ M_2 (passive). Denoting this relation G, we get from (1) and (2) the representation of universal gravity through the same passive mass:

$$F_1 = F_2 = G \cdot \frac{M_1\,(\text{passive}) \cdot M_2\,(\text{passive})}{R^2} \qquad (3)$$

The effect of inertia - resistance of material bodies to changes of their velocity - is measured by a force, F, proportional to the inertial mass and the rate of the velocity changes, the acceleration *a*: F = M (inertial) · *a*. The famous principle of equivalence of inertial and gravitational masses is implicit in Newton's mechanics. It allows determining all masses through their weights. Thus, the principle of equivalence is related to the proportionality of inertial and passive gravitational masses. As stated in [18], "a further distinction between active and passive gravitational mass might be made", however, this possibility is ignored. Establishing masses through their weights is possible because all the corresponding effects are merely proportional to the amount matter.

Yet inertia and gravitation are unrelated effects: the rules of mechanics can be applied independently of the universal gravity. Particularly, the second law of mechanics can be introduced without recourse to the concept of weight, for example, through measuring the pull of rotating bodies [19]. So, the proportionality of the inertial and passive gravitational masses is a lateral factor that does not incur profound physical implications as postulated by general relativity. The dynamical behavior of gravitating bodies is determined not by the passive, but by the active gravitational mass. This circumstance should not be ignored. It is the active gravitational mass that generates the decisive trait of the gravitational mechanism – action-at-the-distance.

General relativity does not incorporate active gravitational mass in its operative facilities. Instead, it relies on gravitational waves that propagate as ripples of the spacetime. It has been expected that "the experimental discovery of gravitational waves would merely confirm the obvious" and that "even more important: gravitational-wave astronomy would be a useful adjunct to optical, radio, and X-ray astronomy" [18]. However, this crucial inference of general relativity is not confirmed by experiments (see [14]). Also, spinning bodies, like a gyroscope, should behave differently depending on whether gravity is impelled by instantaneous action-at-the-distance or through propagating spacetime undulations. Experimental investigations of these effects have not yet reported conclusive results [20].

2.3 Mediation of force: stretching pulses vs. restricted corpuscles

Separated material bodies interact through emanation of mediating agents. Flying apart uniformly from a point source, mediating agents spread over a surface area proportional to R^2, so their density, and hence their impact, decreases inversely to R^2. If mediating agents are restricted corpuscles (Fig. 1-a), a force with an inverse-square dependence on the distance is created. Numerous attempts have been made since Newton's time to accommodate such kind of a scheme to gravitational attraction, but they have not led to any well-established result. "That gravitation is propagated by the action of a medium, and consequently is a process requiring time for its accomplishment, had been an article of faith with many generations of physicists" [13].

This paper presents another attempt to construct a mechanism of gravitation following the given operational scheme. The surmised mechanism has arisen from the cellular automaton model overviewed in the Appendix. For the mathematical analysis of this gravitational mechanism we will focus our attention only on the part of this cellular automaton model that yields solutions in the form of fast spreading constant phase lines (Fig. 1-b). The stretching pulses of these lines produce action-at-the-distance as they spread with a speed substantially faster than the speed of material synchro formations, the incoming pulses exercise a gravitational pull as material synchro formations tend to reposition towards the lines where phase constancy is maintained.

Figuratively, a stretching pulse acts as a harpoon that swiftly hits a target and remains effectual until the trailing rope slowly disintegrates. So, the impact of a stretching pulse can be described as an instantaneous imposition of a synchronized line, which then gradually shrinks from the rear by desynchronization. Thus, at a distance, R, an impact from such a stretching pulse will endure for an interval of time, Δt_R, between the passage of the front and rear activities with the velocities V_f and V_r:

$$\Delta t_R = R \cdot \left(\frac{1}{V_r} - \frac{1}{V_f} \right) \cong R \cdot \frac{1}{V_r} \qquad (4)$$

As will be seen, it has been determined that the front speed, V_f, is extremely high - about $10^{40} \cdot c$ (c is the speed of light); the lower rear speed, V_r, is estimated as $10^{32} \cdot c$.

The operational advantages of the spreading constant phase pulses as force mediating agents lie in the following. In general, mediation agents may encounter a problem with gravitation screening by unrelated bodies. For stretching pulses this problem does not come out: the bulk of a body is transparent to the thin 1D lines, which pierce mostly empty space between the material formations without obstruction. Thus, material bodies undergo instantaneous pairwise interactions of any elements, irrespective of possible screenings. Intermediate bodies placed between interacting bodies not only do not hinder the interaction contacts, but the intermediate bodies themselves participate in the universal gravitational attraction as well. Further, with various types of mediation agents there could be a problem of polluting the Universe with the debris of gravitation mediators that had failed to make their contact. The suggested mechanism is completely

devoid of this problem. The considered mediation agents arise out of nothingness as synchronized lines and dissolve entirely without any trace through desynchronization.

The stretching pulses mechanism leads to the dependence of the attraction force on the distance that is inverse-linear rather than inverse-square. So, what does this mean?

2.4 Gravitational forces in the astronomical and cosmological scale

Two factors determine the force produced by mediating agents: the operational factor measuring their individual impacts and the geometric factor, $1/R^2$, accounting for the spread of these impacts in space. If agents mediating the attraction force were restricted corpuscles (Fig. 1-a) they would produce a fixed impact resulting in the exact inverse-square dependence on the distance: the coefficient G in (3) is a constant. The stretching pulses (Fig. 1-b) produce a changeable impact. So, the constant G in (3) has to be substituted by a transfer function G(R) expressing the dependence of the impacts on the distance:

$$F = G(R) \cdot \frac{M_1\,(\text{passive}) \cdot M_2\,(\text{passive})}{R^2} \qquad (5)$$

The impact of a mediating agent is proportional to the time of its application. Hence, as prescribed by (4), stretching pulses exercise impacts directly proportional to the distance. There is a natural reason for a slight correction to this action: stretching pulses do not start fading away immediately, but after a certain time delay. This ensures the delivery of some minimal impact, G_0, even at a zero distance. Thus, we get:

$$G(R) = G_0 \cdot (1 + R/R_0) \qquad (6)$$

The initial stage of this transfer function has to accommodate a smooth transition from zero. A conceivable approximation would be a horizontal line as indicated in Fig. 2. To obtain the value of the gravitational force we have to multiply the geometric factor $\sim 1/R^2$ by the operational factor, a transition function like (6) with corresponding modifications. The horizontal line approximation presents Newton's inverse-square law; the gravitational constant G equals approximately the parameter G_0. The parameter R_0 is the characteristic distance for the stretching pulses mechanism, the distance where both impacts - regular Newtonian and increased by stretching pulses - become comparable.

The characteristic distance R_0 establishes a watershed between the two differing approximations for gravitational attraction determined by the transfer function regions: constant or linear. The case $R << R_0$ presents the astronomical scale: gravitational forces between the bodies are approximately inversely proportional to the second power of the distance. The case $R >> R_0$ presents the cosmological scale: gravitational forces between the bodies are approximately inversely proportional to the first power of the distance.

3. Contemplating the outcomes of the stretching pulses mechanism

3.1 The faraway intensifications

3.1.1 Spherical configurations with inverse-linear gravity

We will examine the specifics of gravitational dynamics in the cosmological scale under the inverse-linear attraction force using a proportionality relationship:

$$\text{Elemental_unit_force} \sim (\rho \cdot dV)/R \tag{7}$$

Here ρ is the density of the active gravitational mass, dV is an elemental volume, and R is a distance.

We will concentrate on a basic structure: a uniform sphere of radius R_E falling in the cosmological scale, $R_E >> R_0$. For Newton's inverse-square law the dependence of the gravitational force on the distance from the center of a uniform sphere is simple: inside the sphere the attraction force grows linearly, outside of the sphere it decreases as $1/R^2$. In the case of the inverse-linear law this dependence is more complicated.

First, let us consider an elemental spherical layer of gravitating matter of a certain radius R (Fig. 3). For the inverse-square law the force acting upon a material body anywhere inside this layer will be exactly zero; for the inverse-linear law the inside force will depend on the distance from the center, r; we will denote it $F(r,R)\cdot dR$. To evaluate the integral presenting this inside force we specify a conic rim within the considered spherical layer at angle φ of angular width $d\varphi$, so all the elements of this rim will be at a fixed distance l from the given point, and thus produce the same force inversely proportional to l (Fig.3). The value of l is determined by the relationship: $l^2 = R^2 - 2Rr\cdot\cos\varphi + r^2$. The resultant force from the conic rim at angle φ, $dF(\varphi; r,R)$, is the sum of projections of all the attraction forces from all the elements of the indicated rim:

$$dF(\varphi; r,R) \sim -\frac{\rho\cdot 2\pi R^2 dR \cdot (R\cdot\cos\varphi - r)\cdot \sin\varphi \cdot d\varphi}{(R^2 - 2Rr\cdot\cos\varphi + r^2)} \tag{8}$$

The minus sign denotes the direction towards the center. The total force, F(r,R), will be the integral of $dF(\varphi;r,R)$ over φ from 0 to π. For Newton's law, the corresponding expression for $dF(\varphi;r,R)$ will look the same as (8) except that the denominator will contain the distance l in one unit higher power; expectedly, in this case the integral for the total force turns out 0. For the inverse-linear law, substituting $\cos\varphi = x$ in (8) yields

$$F(r,R)\cdot dR \sim -\frac{\rho\cdot\pi R^2 dR}{r}\cdot\int_{-1}^{+1}\frac{(x - r/R)\cdot dx}{((R^2+r^2)/2Rr - x)} \tag{9}$$

Evaluating the integral in (9) we get:

$$F(r,R)\cdot dR \sim -\rho\cdot 4\pi R\cdot dR\cdot [(1/3)\cdot(r/R) + (1/15)\cdot(r/R)^3 + \ldots (1/(2k-1)(2k+1))\cdot(r/R)^{k-1} + \ldots] \quad (10)$$

Thus, the inverse-linear law produces a force of attraction (10) towards the center. The factor $\rho\cdot 4\pi R dR$ is the mass of the spherical layer, M_{SL}. We can estimate the attraction force, F_0, near the center of the spherical layer, $r << R$, and the attraction force, F_b, near its boundary, $r \approx R$:

$$F_0 \sim (M_{SL}/R)\cdot(1/3)\cdot(r/R) \quad (11)$$

$$F_b \sim (M_{SL}/R)\cdot(1/2) \quad (12)$$

So, the attraction near the boundary of a hollow thin spherical layer is about half of the attraction to the same mass if it all were in the center. Note, that for Newton's inverse-square law any force inside a spherical layer strictly equals zero.

Gravitational force acting upon a point inside a uniform sphere of radius R_E at a distance r form the center, $F(r,R_E)$, comes from two separate components: attraction from the internal spherical core, $F_{core}(r)$, and attraction from the surrounding shell - external thick spherical layer, $F_{shell}(r)$: $F(r,R_E) = F_{core}(r) + F_{shell}(r)$. The obtained result (10) allows calculating $F_{shell}(r)$ by integrating the attractions of elemental spherical layers over R from r to R_E. With a substitution $\xi = r/R$ we get:

$$\int_r^{R_E} F(r,R)\cdot dR = \int_1^{r/R_E} \rho\cdot 4\pi r^2\cdot[(1/1\cdot 3)\cdot\xi + (1/3\cdot 5)\cdot\xi^3 + (1/5\cdot 7)\cdot\xi^5 + (1/7\cdot 9)\cdot\xi^7 + \ldots]\cdot d\xi/\xi^3 \quad (13)$$

This expression presents the force acting at a point at distance r from the center of a uniform spherical shell of radius R_E. Calculations go straightforward; for the polynomial terms the small integration limit r/R_E is replaced by zero:

$$F_{shell}(r) \sim \rho\cdot 4\pi r^2\cdot[-(1/3)\cdot(R_E/r) + 1/3 - ((1/1\cdot 3\cdot 5) + (1/3\cdot 5\cdot 7) + (1/5\cdot 7\cdot 9) + \ldots)] \quad (14)$$

The sum of the series, S, is evaluated as:

$$S = 1/1\cdot 3\cdot 5 + 1/3\cdot 5\cdot 7 + \ldots = \tfrac{1}{4}\cdot\{[1/(1\cdot 3) - 1/(3\cdot 5)] + [1/(3\cdot 5) - 1/(5\cdot 7)] + \ldots\} = 1/12 \quad (15)$$

Thus, recognizing the mass of the internal core $M_{core} = (4/3)\cdot\pi r^3\cdot\rho$, we get the external force from the surrounding shell:

$$F_{shell}(r) \sim -(M_{core}/r)\cdot(R_E/r) + 0.25\cdot(M_{core}/r) \quad (16)$$

Now, let us evaluate the internal attraction force from the core of radius r itself. For Newtonian inverse-square law, the attraction force to a sphere of a radius r outside of this sphere at a distance L from its center, $L > r$, will be $\sim M/L^2$ irrespectively of the values of r and L. For the inverse-linear law, the attraction force acting at a faraway distance, L,

from the center of the sphere, $L >> r$, would be apparently $\sim M/L$. In general, to get the dependence of the attraction force at an outside point x at a distance L(x) from the center of the given sphere, F(r,L), we need to perform an integration over the volume, V, of this sphere:

$$F(r,L) \sim \iiint_V \rho \cdot dV/L(x) \qquad (17)$$

Calculation of the integral (17) is a little bit strenuous exercise. The result can be obtained, in particular, through cutting the volume V by spherical bases of conic sectors at definite distances from x. Thus, we will get:

$$F(r,L) \sim -(M/L) - (M/r) \cdot 3 \cdot [(1/1 \cdot 3 \cdot 5)(r/L)^3 + (1/3 \cdot 5 \cdot 7)(r/L)^5 + \ldots] \qquad (18)$$

For large distances, $L \to \infty$, this provides as expected

$$F(r, \infty) \sim -(M/L) \qquad (19)$$

For a point at the surface of the internal core, $L = r$, taking into account the result for the sum (15), the expression (18) gives a result for the internal force:

$$F_{core}(r) \sim -(M_{core}/r) \cdot (5/4) \qquad (20)$$

Finally, we have the total force, $F(r, R_E)$, acting upon a point inside a uniform sphere of gravitating matter at distance r from the center as the sum of (20) and (16):

$$F(r, R_E) = F_{core}(r) + F_{shell}(r) \sim -(M_{core}/r) \cdot (1 + (R_E/r)) \qquad (21)$$

Formula (21) shows how gravitational attraction arising inside a big uniform sphere is affected by the distance, r, from the center of this sphere: $0 < r < R_E$. Since the mass of the internal spherical core grows as r^3 the force will change with r as $\sim (r^2 + R_E \cdot r)$. In a similar situation Newton's inverse-square law produces a simpler dependence: $\sim r$. Thus, the relation of the inverse-linear and inverse-square forces will be:

$$\frac{\text{Inverse_linear_force}}{\text{Inverse_square_force}} \approx 1/R_0 \cdot (r + R_E) \qquad (22)$$

This comparison is valid for the cosmological scale when $R_E >> R_0$. The proportionality coefficient $1/R_0$ comes from considering (3) with regard to (5) and (6). Thus, say R_E is ten times R_0, then the inverse-linear gravitational force will exceed Newton's force by about 10 times near the center and by about 20 times at the boundary of the given sphere. Outside of this sphere the inverse-linear force will decline in accordance with the formula (18) maintaining its preponderance over Newton's force, roughly in proportion to the distance.

3.1.2 Flatness of the rotation curves

The perplexing deficit of gravity in galactic motions can be compensated assuming the inverse-linear dependence of the attraction force. The major puzzle is that the velocity of the rotating objects in spiral galaxies, V, is too high for the attraction of conventional gravity. The centripetal acceleration of an object at a distance R from the center is $\boldsymbol{v}^2/R$. Considering that a substantial part of the galaxy mass is around its center, the acceleration from Newton' gravity would be GM/R^2. These two accelerations should be balanced resulting in the rotation curve $\boldsymbol{v} \sim R^{-1/2}$. Thus, $\boldsymbol{v}$ has to gradually decline with R: the further is an object from the center the slower it rotates, as happens in the astronomical scale within the Solar system. Surprisingly, in the cosmological scale in galaxies the rotation curves mainly appear flat, i.e. the velocity $\boldsymbol{v}$ stays approximately constant irrespectively of the distance from the center. Even more, the velocity V maintains constancy beyond the edge of the visible matter. For the case of inverse-linear gravity the centripetal acceleration is to be equated with GM/R. This produces a flat rotation curve $\boldsymbol{v} \approx$ constant.

Typically, the density of visible matter in galaxies rapidly decreases with moving away from the center. Therefore, to explain the flat rotation curves with regular gravity it is necessary to assume that galaxies contain a substantial amount of invisible "dark matter". Strangely, "dark matter" always embodies luminous matter and transpires in a form of spherically symmetric haloes. With the suggested mechanism the explanation of the halo configurations of the "dark matter" is obvious: the amplification of the gravitational attraction is due to stretching pulses stemming from the luminous matter, so it will always appear that the alleged "dark matter" surrounds the original material structures.

The idea that the deficit of gravity in galactic motions can be explained assuming the inverse-linear dependence of the attraction force rather than "dark matter" has been considered and discussed in different variations by a number of researchers (see, e.g. [21]). The work [21] indicates a specific drawback of this approach: the masses of the galaxies do not scale appropriately with the Tully-Fisher law, an empirical relationship between the galaxy luminosity and its rotational speed. Theoretical considerations of this subject as presented in [21] assume that the attraction force to a sphere in the case of inverse-linear law is inversely proportional to the distance from the center of this sphere, 1/R, in parallel with Newton's law where this attraction is inversely proportional to the square of the distance, $1/R^2$, for any size of the sphere. This Newton's theorem is true for the inverse-square dependence, but its straightforward transference to the inverse-linear dependence should be restrained. The inverse-linear force is exercised just by a point source, or by a finite sphere at infinite distance. The situation with finite spheres and finite distances is more complicated as expressed by formula (18). In these circumstances, especially for non-uniform densities, the consideration of Tully-Fisher relationship might involve geometric factors lessening the scaling restrictions.

Another distinctive thing that affects the dynamics of galaxies under the inverse-linear gravity is the influence of the surrounding shell of gravitating matter. As can be seen from the formula (16) for the inverse-linear gravity this influence appears quite

substantial, while in Newton's case it will be zero. The presented analysis is applicable to spherical shells with a uniform density of matter. In configurations with non-uniform distributions the surrounding shell can produce unusual actions, and even exercise repulsion rather than attraction. This, for example, can explain an atypical absence of "dark matter" near galaxy center as has been recently reported for galaxy NGC3379 [3]. One also should bear in mind a possible influence of external shell when interpreting observations that may not be completely compatible with straightly inferred distributions of the "dark matter".

3.1.3 Equilibrium velocities in galactic systems

The velocities of motions of galaxies in clusters and superclusters surpass the limits that can be handled by conventional gravity even more drastically. Thus, it has been evaluated that the amount of "dark matter" required to maintain the observed galactic motions might exceed the amount of luminous matter in about 100 times. Galactic systems do not have well-defined orbiting components to directly verify the gravitational balance. In this situation it is only possible to rely on the comparison of statistical characteristics of these systems.

For a mechanical system in dynamical equilibrium moving in a limited space under the action of Newtonian attraction force there is a simple relationship between the average speed of the gravitating objects and spatial layout of their mass, i.e. between average kinetic, T, and potential, U, energies:

$$2 \cdot T = -U \tag{23}$$

So, if the value of T is too high to be matched with U one may assume that an extra "dark matter" is needed to hold the integrity of the galactic systems.

The relationship (23) is a particular case of a more general notion of mechanics presented by the virial theorem (see, e.g. [22]). Let us consider how this notion can be applied to systems with inverse-linear gravity. To simplify the theoretical analysis, we substitute this inverse-linear dependence, 1/R, with an approximation where the distance exponent slightly exceeds 1:

$$\frac{1}{R} \approx \frac{1}{R^{1+\varepsilon}} \tag{24}$$

The exact inverse-linear law corresponds to $\varepsilon = 0$, while in this consideration ε is treated as a small positive value. The Newtonian inverse-square law turns up at $\varepsilon = 1$. Employing the approximation (24) facilitates the comparisons.

Derivation of the virial theorem in [22] starting with averaging the parameters of the system using Newton's law of dynamics utilizes the expression:

$$2 \cdot T = \sum_i \mathbf{R}_i \cdot \frac{\partial U}{\partial \mathbf{R}_i} \qquad (25)$$

The sum is taken over all objects of the system. The components of the force are determined as partial derivatives of the potential function U; the condition $U(R) \rightarrow 0$ when $R \rightarrow \infty$ is not satisfied for the 1/R force, but fulfils for the case $1/R^{1+\varepsilon}$. For the force presented as $1/R^{1+\varepsilon}$ the equation (25) yields:

$$2 \cdot T = \sum_i GM_i/R^{\varepsilon} \sim GM/R^{\varepsilon}_{average} \qquad (26)$$

Here M_i are masses of individual objects and M is the total mass of the system. The mean value of $R_{average}$ is somewhere within the range of distances between the objects. For the Newtonian inverse-square gravity, $\varepsilon = 1$, further elaboration of (26) would lead to the common formulation of the virial theorem (23).

The comparison of statistical dynamics of galactic systems under the inverse-square and inverse-linear laws of gravity can be conveniently performed with the expression (26). The assumption of equilibrium required for the validity of the statistical evaluation of the motions of galactic systems implies that these systems have to be compact. In such systems without wide variations of distances between the galaxies the values of $R_{average}$ should be relatively close for different ε. With this supposition the expression (26) shows that the average kinetic energy for the case of small ε would be substantially bigger than for the case $\varepsilon = 1$.

Thus, the inverse-linear gravity produces substantially higher velocities of galactic motions than the inverse-square gravity. On the other hand, the relationship (26) indicates that sticking to the inverse-square gravity the explanation of higher than expected galactic velocities would require substantially more total mass for the galaxy systems.

The deficits of gravity discovered in both types of stellar motions – rotational velocities in spiral galaxies and average velocities of galaxies in clusters – result from the same inverse-linear behavior of gravity in the cosmological scale. The alleged appearance of "dark matter" in galactic systems implies that the operational range of the suggested stretching pulse mechanism spreads out well beyond the typical size of galaxies.

3.2 The nearby deflections

3.2.1 Precession of planetary orbits

In a short range, in the astronomical scale, the mechanism of stretching pulses delivers at the onset a constant impact bringing in the ordinary inverse-square attraction (see Fig. 2). It is natural to expect smoothed transitions to and from this constancy. So, investigations

of the initial borderline variations could provide an underpinning for the anticipation of a further increase of gravity.

One of the most impressive achievements of Einstein's theory of general relativity is the explanation of precession of the planetary orbits that has exactly accounted for a perplexing advancement of the perihelion of Mercury. There are several other explanations of precession of the planetary orbits due to possible tiny deviations from Newton's law [13], but these explanations are less satisfactory because of a fewer accuracy and extraneous predictions.

Our mechanism readily produces an explanation for the precession of the close planetary orbits since its initial gravitational attraction goes slightly below Newton's law. Subsequently, the gravitational attraction increases as it undergoes a transition from inverse-square to inverse-linear dependence. This increase of gravity may be related to surprising findings for distant regions of the solar system - the so-called "Pioneer Anomaly" to be discussed in the next section. The two effects - the precession of planetary orbits and the "Pioneer Anomaly" - come from divergences of different signs. Markedly, Einstein's theory of gravitation predicts the exact value for the advancement of the perihelion of Mercury. So, it may not be capable to account for an effect of an opposite sign.

Any small deviation from the inverse square dependence of the attraction force leads to precession of the ideal elliptical orbits (see, [22]; particularly, exercise 3-b in Chapter 3, §15). Considering a quadratic correction to the transfer function (6), the attraction force in the area near the Sun, $F_{near}(R)$, would be

$$F_{near}(R) \sim -\frac{M_{Sun}}{R^2} + \frac{M_{Sun} \cdot \chi}{R^4} \qquad (27)$$

where M_{Sun} is the mass of the Sun and χ is some undefined coefficient. After appropriate transformations that bring (27) in agreement with the notation of [22], the value for $\delta\varphi$ – a change per one revolution of the angle for the elliptic orbit axis direction – is obtained:

$$\delta\varphi \approx -\frac{2 \cdot \pi \cdot \chi}{p^2} \qquad (28)$$

Here p is the parameter of the ellipse: semi-length of the chord going through the focus perpendicularly to the major axis (p = (Aphelion·Perihelion)/ Semi-major axis). Using the formula (28) we can compare the results for the advancements of the perihelion for different planets (data for the Table 1 have been taken from [23]). As the coefficient χ is unknown, we have used the Mercury data as a reference point for the proportionality calculations with (28).

Table 1. Precessions of planetary orbits in arc seconds per century

	General Relativity	Observations	Stretching Pulses Mechanism
Mercury	43.0	43.1 ± 0.5	43.1 (reference point)
Venus	8.6	8.4 ± 4.8	11.3 (calculated with (28))
Earth	3.8	5.0 ± 1.2	5.9 (calculated with (28))

By establishing the value of χ through the Mercury data, we can evaluate the decrease in Sun's gravitational attraction for different planets. According to (27), the gravitational force for a planet at a distance R from the Sun is decreased relatively to the force of Newton's law by a small fraction:

$$\text{Relative Decrease of Gravity} \approx \frac{\chi}{R^2} \qquad (29)$$

For Mercury, the 43.1 arc seconds of precession for century translates into 10^{-6} radians of $\delta\varphi$ per one revolution. The parameter p for Mercury in Astronomical Units (AU) is 0.37. Having (28), we evaluate $\chi = 0.66 \cdot 10^{-7} \cdot (\text{AU})^2$, and then compile the results using (29).

Table 2. Relative decreases of gravity with respect to Newton's law

	Distance in AU	Fraction of force below the inverse-square value
Mercury	0.39	$4.3 \cdot 10^{-7}$
Venus	0.72	$1.3 \cdot 10^{-7}$
Earth	1.0	$0.7 \cdot 10^{-7}$
Mars	1.52	$0.3 \cdot 10^{-7}$

For elongated orbits the situation with the precession appears more complicated. Thus, the orbit of the asteroid Icarus, which spans from 0.19 AU perihelion to 1.97 AU aphelion, has the rate of precession five times less than predicted by our proportionality calculations using (28), yet the results based on general relativity are satisfactory. In our view, this may happen because in a wider range the dependence of gravitational attraction on the distance does not follow exactly the simplified quadratic deviation assumed in (27). For celestial objects on oblong elliptic orbits the effects due to suspected increased gravity could be more tangible. An emblematic example of such an object presents Halley's Comet. After taking into account all possible factors, the prediction of perihelion of Haley's Comet 1986 was accurate up to about six hours [24]. It could be inquisitive to redo these calculations considering the supposition of the additional gravity.

3.2.2 Space probes: the "Pioneer Anomaly" and flybys

Modern space technology allows for experimental investigations of gravity utilizing spacecrafts as artificial celestial bodies. The velocities of the spacecrafts are measured directly by Doppler's shifts with high accuracy sufficient to handle very small changes.

An intriguing happening that has raised recently a great interest presents what is called the "Pioneer Anomaly" [25]. In 1972 and 1973 the Pioneer 10 and 11 spacecrafts were launched to explore the outer solar system. Yet the baffling peculiarities in Pioneers 10 and 11 motions overshadow their achievements as the first missions to Jupiter and Saturn. By 1980 Pioneer 10 had passed a distance of ~ 20 AU (Astronomical Units) from the Sun an anomaly in the Doppler signal showing a deviation of its trajectory became evident. It was anticipated that an additional gravity of some previously undiscovered planet would pull the spacecraft out of course, but instead of pointing outside of the solar system the appearing force pointed inwards. Similar things happened to Pioneer 11 at the opposite side of the solar system.

Possible explanations are combined in four categories: misunderstanding of how the gravity works, misunderstanding of inertia and forces, malfunctions on board of the spacecraft, and defects of the tracking station on Earth. Technical causes are still not completely excluded [26], so deliberations on new fundamental physical notions should be reserved.

For the suggested mechanism of gravitation the "Pioneer Anomaly" could be used to test the main trait of this mechanism - perfect spherical symmetry. Other explanations, for example, employing "dark matter" may not necessarily imply spherical symmetry, while this mechanism foresees the same increases of gravity at the same distances from the Sun in all directions. This anticipation has been already backed up by the data from the opposite flights of Pioneers 10 and 11. Further verification of this property could be instrumental with flights orthogonal to the ecliptic plane.

Certain gravitational irregularities have been observed in the planetary flyby maneuvers. These maneuvers present an indispensable well-elaborated technique to handle energy problems in the interplanetary missions; they are used to change orbital velocity of a spacecraft by its gravitational interaction with a planet [27].

Velocities of the spacecrafts in these maneuvers are calculated and detected with a very high degree of accuracy. And the observed effect came as a great surprise: spacecrafts in flybys suddenly accelerate for no apparent reason. This acceleration in flybys is not a sporadic effect, it appears systematically. Thus, the space probes *Galileo, NEAR, Cassini-Huygens* and *Rosetta,* all experienced unexplained boosts of 3.9 mm/s, 13 mm/s, 0.11 mm/s and 2 mm/s respectively. The observed excess in velocity is much larger than the errors in measurement. After canceling out all possible explanations, it remains to assume that the answer may lie in abnormal properties of gravity [27].

The alleged gravitational abnormalities in the "Pioneer Anomaly" and flyby maneuvers should be somehow related [28]. For the suggested gravitational mechanism its impact as shown in Fig. 2 goes first below and then above the horizontal line of Newton's approximation. Again, the deviation in the "Pioneer Anomaly" is of an opposite sign to that in the flyby effect: at far-off distances where gravitation is above Newton's law a

spacecraft undergoes deceleration, at short distances where gravitation is below Newton's law a spacecraft acquires an extra boost.

It is important to emphasize the possibility of applying flyby maneuvers to the investigation of fine details in the gravitational field configurations. A flyby encounter can be treated as an elastic collision of a spacecraft and a planet. Thus, flyby experiments can be used analogously to scattering experiments in nuclear physics probing a field surrounding a given body.

3.3 Hypotheses and speculations

3.3.1 The astronomical-cosmological watershed

The presented analysis shows the mathematical principles to which the suggested gravitation mechanism obeys. Realizing this mechanism in a broader context would need further operational hypotheses. At this time we just can resort to tentative speculations.

As expressed by formula (6) and delineated in Fig. 2 the gravitational impact is determined by two major parameters, G_0 and R_0. The parameter G_0 is approximately equal to the gravitational constant G in Newton's law (3). The parameter R_0, the watershed between the astronomical, inverse-square, and cosmological, inverse-linear, cases, is the inverse of the slope in the main part of the transfer function (6).

To evaluate R_0 let us manipulate with the data on the precession of planetary orbits (Table 2) and on the "Pioneer Anomaly" [25]. It appears that the transfer function for the gravitational attraction to the Sun should have an inflection point somewhere between Mercury and Jupiter. Say, this occurs in the middle at ~ 2.5 AU. So, it is reasonable to assume that in the region of Jupiter the relative deviation of the transfer function would be about the same as for Mercury, $\sim 4 \cdot 10^{-7}$, but of the opposite sign. In fact, taking the value for Pioneers extra deceleration near Jupiter from data in [25] as $\sim 1 \cdot 10^{-13}$ km/sec^2 and relating it to Newton's attraction at this distance we actually get the fraction of the same absolute value $\sim 4 \cdot 10^{-7}$.

As the distance grows the transfer function in Fig. 2 should become more flat. Thus, its tangent in the cosmological region, $1/R_0$, would be less than its tangent in the astronomical region. The latter can be estimated using the above-indicated deviations from Newton's law for Mercury and Jupiter. Thus, we get

$$R_0 > \frac{5\ \text{AU} - 0.4\ \text{AU}}{4 \cdot 10^{-7} - (-4 \cdot 10^{-7})} \approx 100\ \text{light-years} \qquad (30)$$

The obtained specification of 100 light-years as a lower bound for the borderline between astronomical and cosmological regions looks reasonable. This means the following: when distances are somehow below 100 light-years the movements of celestial bodies would go

in accord with Newton's law; when the distances are far above 100 light-years explanations of the movements of celestial bodies appeal to "dark matter".

The range of the astronomical scale can be evaluated also on the basis of microphysics considerations. The transfer function (6) gets a plateau instead of gradual rising from zero since the desynchronization of constant phase lines is delayed. This delay can be related to the shortest time characterizing microscopic events of about 10^{-25} sec - the time for light to cross the proton. In this time interval, the desynchronization process propagating with the speed of $10^{32} \cdot c$ will spread over 2000 AU. Thus, the plateau in the transfer function (6), and hence Newton's law of gravitation, could span over such a distance.

3.3.2 Ultra small distances

Our considerations do not impose any particular conditions on the gravitational force at very short distances. Although general suppositions entail that in a short-range the deviations of gravitational force from Newton's inverse-square law should be substantial.

Several clues of suspected deviations from Newton's law have led to the search for a "fifth" force [29]. A new type of low-mass gravitation-coupling particle was suggested producing a force of about a percent of gravity in a range of few hundred meters. However, numerous experiments undertaken in search of the "fifth" force did not provide positive results.

The applicability of Newton's law to gravitational force at ordinary small distances had been verified in the famous Cavendish's experiments. Now, following the string theory suggestions and involving different particles there have appeared ideas that the inverse-square behavior of gravity could break below the centimeter range. Yet no such deviations have been found.

As to our gravitation mechanism, the suggested operational scheme definitely shows that gravitational attraction in the microscopic scale could not develop at all. This leaves the question on the onset of the gravitational transfer function open.

3.3.3 Ultra large distances

Evidently, the mediating capacity of stretching pulses cannot go unrestrictedly over the whole range of distances. Beyond the main mode of the disappearance of stretching pulses by fading away due to the desynchronization beginning at the source, a possible scenario could also include loss of the synchronization of stretching pulses all along their way. Under these circumstances, a saturation plateau would cut off the growth of the transfer function after a certain interval as shown in Fig. 2. Possibly, beyond the saturation point, at very large distances, the gravitational attraction between the galaxies will look again Newtonian, yet with a significantly increased gravitational constant.

Another vital question is how far can the stretching pulses go by themselves with respect to the size of the Universe. If the stretching pulses can extend over the whole Universe a

curious effect may arise. In unbounded 3D space the agents of gravitational action spread over area increasing as $\sim R^2$. As long as the Universe is considered bounded as 3D surface of a 4D hypersphere the gravitational agents after initial R^2 spreading will be concentrated in a narrow area at the site diametrically opposite to the source. So, in these extremely remote areas gravitational impact would be significantly increased. This hypothetical far side concentration of a gravitational impact might produce an appearance of the effects associated with the black holes.

4. Concluding remarks

Since Newton had established the mathematical principles for the universal gravity there had been undertaken many attempts to devise an operational mechanism that could these principles implement. However, none of these attempts succeeded. The portrayal of gravity by Einstein's theory of general relativity is just another mathematical description of this phenomenon rather than an operational mechanism.

The presented paper suggests a mechanism of gravitation with a particular type of mediation agents in the form of stretching pulses. The mathematical description of the given operational scheme corresponds to a common inverse-linear modification of Newton's law that has been already explored in view of the observed gravitational abnormalities. This modification effectively confronts the foremost puzzle of modern physics - a huge deficit of gravitational attraction in the cosmological scale appearing as the so-called "dark matter". Equally well it can treat the alleged tiny gravitational anomalies in the astronomical scale.

The vital distinction of this work is that the surmised mechanism of gravitation does not introduce an *ad hoc* solution to fix certain observed peculiarities. Instead, this mechanism naturally arises from the intrinsic non-locality of a general cellular automaton model of the physical world that has been developed earlier with absolutely no relationship whatsoever to the problems of gravitation.

The workings of gravitation stay separately from the rest of physics. For traditional physics it is not clear why gravity is so much weaker than the other forces of Nature. All physical theories encounter insurmountable difficulties trying to unify gravitation with different phenomena. These difficulties are in the heart of the crisis of modern physics (see, e.g. [30]).

In our case the situation is quite the opposite. In the developed cellular automaton model of the physical Universe the phenomenon of gravitation appears as an intrinsic component of the whole system - an inherent part of its non-locality. Thus, it becomes not easy to separate the description of gravitation out of the whole picture of the physical world. In this respect, to view the general properties of gravitation in a broader context we have to refer to the Appendix.

5. Appendix: A cellular automaton framework placing gravitation among the four fundamental forces of Nature

1. **The distributed operational machinery.** The idea of representing the physical world with cellular automata was conceived by K. Zuse and E. Fredkin [31,32]. A cellular automaton is a regular grid of nodes whose states are transformed in discrete steps depending on the states of the surrounding neighbors (see e.g. [33, 34]). Potentials of the cellular automata for the representation of the physical world are best envisioned with the famous Conway's "Game of Life", which generates intriguing patterns using a simple rule. Certain patterns in this cellular automaton, "gliders", present stable relocating configurations; thus, it is tempting to find a cellular automaton rule producing a number of stable relocating configurations, which could be identified with elementary constituents of matter. Hopefully, the behavior of these material formations could go with the established laws of physics. So, the phenomena of the physical world are expected to emerge from the underneath cellular automaton transformations, similarly to what supposedly appears from the virtual activities of quantum vacuum.

2. **The undetectable absolute space of cellular automata.** The cellular automaton construction for the physical Universe is a high-tech resurrection of the classical concept of ether that has been discarded, perhaps "undeservedly" (see [35]). The specificity of cellular automata is that motion of their material formations is performed through reconfigurations over the medium rather than by passing through it. This elucidates the seemingly scholastic proposition of Lorentz and Poincaré that absolute motion exists but is undetectable. The absolute nature of motion being hidden, the notorious confrontation with the postulate of relativity for a cellular automaton ether is avoided.

Realization of the material formations by cellular automata resolves the principal problem of inertia. The uniform motion of material formations is supported by the underlying cellular automaton mechanism. So, material bodies get uniform motion for "free" and maintain it without any perceptible cause in accordance with the first law of mechanics. The inertial mass is a measure of action required to change the uniform motion of a body, it is proportional to the amount of material formations involved. This corresponds to Newton's view on classical mechanics, and substantiates his presumably illogical definition of mass as a product of density by volume.

3. **The prerequisite of mutual synchronization.** Realization of the cellular automaton model of the Universe involves two major concerns. First: trying to find a cellular automaton rule that can produce the required complex behavior of physical objects seems impossible. Second: it is not clear whether local transformations can account for the apparent non-locality of the Universe. A total trial-and-error search for the desired cellular automaton mechanism by intensive computer simulations is hopeless. Adhering to a cogent guiding principle, one should think of this mechanism not as of a model to be simulated, but as of a construction to be actually implemented. In the first place, implementation of such a construction needs a distributed clock; it has to be robust, and hence fault-tolerant. This requirement removes any arbitrariness in the choice of the

primitive rule of Nature. The cellular automaton mechanism underlying the physical world must contain a grid of mutually synchronizing circular counters; the state of the system is characterized by a distribution of the phases θ ($0 < \theta < 2\pi$) defining the relative states of the counters. Astoundingly, but this approach solves the problem.

It turns out that the whole richness of the physical world condenses in a plain sentence: "All physical phenomena are different aspects of the high-level description of distributed processes of mutual synchronization in a network of digital clocks" [11]. The developed model was named CAETERIS (Cellular Automaton EThER InfraStructure). Workings of this model have been presented in several publications starting [9], in various aspects they are described in [10, 11,12, 36, 37]. The essence of the mutual synchronization activities is described by the following equation:

$$\frac{\partial \vartheta}{\partial t} = -b\vartheta + D_1\Delta\vartheta + D_2\Delta^2\vartheta + D_3\Delta^3\vartheta \qquad (\mathrm{mod}\, 2\pi) \qquad (31)$$

These mutual synchronization activities with certain additional conditions demonstrate two tracks in the arrangement of the physical world as depicted in Fig. 4. One of them reveals the marvels of non-locality.

4. **Spectrum of elementary particles in the form of traveling wave solutions.** A number of areas of physics use media similar to cellular automata, like Ising's model, lattice in quantum chromodynamics, and various condense matter systems. Most closely the cellular automaton ether resembles the model of quantum vacuum, where elementary particles of matter are stable and transient "excitons". The synchronization activity of the "excitons" in the CAETERIS model shows a collection of helicoidal traveling wave solutions (Fig. 4). With an appropriate interpretation one can see that these CAETERIS "excitons" exactly correspond to the spectrum of stable elementary particles (Fig. 5).

Furthermore, the material synchro formations of the CAETERIS enjoy the corresponding physical properties as well. Those include: the law of inertia as traveling waves synchro formations get their uniform motion for "free" from the cellular automaton mechanism, an upper bound on the speed of the material synchro formations – the speed of light, antimatter as dual solutions having an opposite sense of rotation, slight asymmetry between matter and antimatter, and hence prevalence of the matter, which arises from the necessity for an arbitration protocol. A curious reader can delve into detailed comparisons and find parallels with other properties of the physical world.

5. **Operational machinery due to fast spreading diffusion.** Quantum entanglement is the foremost physical phenomenon, which definitely points out that the Universe possesses the property of non-locality. The surmised action-at-the-distance in gravitation is another indication of the physical manifestation of this property. On the other hand, non-locality plays a vital role in biological information processing [36]. The operational background of non-locality is indispensable for the overall organization of the Universe. No general model of Nature, the so-called Theory-of-Everything (see [38] for the most recent developments), can fulfill its aspirations if it does not have non-locality.

The CAETERIS model shows the origin of non-locality with ease. Besides the traveling wave "exciton" solutions this model includes underneath processes due to very fast spreading diffusion solutions. In the CAETERIS model, the elementary particles - "excitons"- come from the parabolic partial differential equation (31) describing the phase diffusion in the cellular automaton mechanism of distributed synchronization. The non-locality originates from the paradoxical property of the parabolic equations: the diffusion impact spreads instantaneously.

The physical reason for the mathematical paradox of the instantaneity in parabolic equations is that these equations describe spreading of smoothed macroscopic values, like "temperature", "density", or "phase amassment". These values are formed by an averaging process that incurs temporal delays while outlying microscopic activities can stretch significantly faster. "Instantaneous" impact takes place below the "slow" averaged amassment of phases in the course of mutual synchronization. The representation of spreading diffusion by parabolic equations is a mathematical idealization, which in a strict physical sense is deficient. So, behind such a simplified presentation of diffusion by parabolic equations there should be a very fast propagating wave mechanism [39].

The opinion that "the action-at-the-distance" is inadmissible from the philosophical standpoint is flawed. There is absolutely nothing outlandish in having a system with two types of processes developing in substantially different time scales. This is a typical situation for relatively slow material systems under essentially faster information control. Thus, besides gravitation and quantum mechanics the non-locality effects are determinedly involved in biological information processing producing trains of ultra-fast diffusion waves for a reference beam of the holographic Universe [36].

6. **Two global periodic processes in the Universe.** Disregard of non-locality leads to major disorientation of modern physics. "The construction of the world seems to be based on two pure numbers, α and ε, whose mystery we have not yet penetrated" [40]. The factor $\alpha = 1/137$, the fine structure constant, appears in relation to interaction of matter with electromagnetic radiation. The number $\varepsilon \sim 10^{40}$ characterizing the relative strength of gravitational interaction is more mysterious: "A simple mathematical theory may lead to numbers like ½ or 8π, but hardly to a non-dimensional number of extravagant order of magnitude 10^{41}".

Presumably, from the standpoint of the CAETERIS model the two dimensionless parameters of the physical world: $\alpha = 1/137$ and $\varepsilon \sim 10^{40}$ are artifacts of the construction. The former parameter is somehow associated with the fraction of the cycle of circular counters that must be put aside for the purpose of fault-tolerance. The latter parameter characterizes the isolated aspect of the spreading diffusional impact. The two types of solutions in relation to these parameters are completely different (Fig.4). Helicoidal traveling waves correspond to material and electromagnetic processes developing in the interval of speeds $(1/137 - 1) \cdot c$. The stretching diffusion produces an "instantaneous" finite impact at $t \rightarrow 0$. The diffusional waves that create the ensuing effects of non-locality happen to propagate with speed about $10^{40} \cdot c$.

Accordingly, the CAETERIS model features two kinds of global periodic processes: the sequence of slow mater creations interpreted as Big Bangs and generation of trains of diffusion waves serving as the reference beam for the holographic mechanism of the Universe. In the aspect of the global constitution of the Universe the developed model turns to combine all seemingly disjoint controversial astrophysical facts into a coherent cosmological picture, see [36, 37] for consideration of the general cosmological issues. As to this paper it is important to point toward one of the results of these considerations regarding the "action-at-the-distance" of the stretching pulse mechanism (see formula (4)). Initially, stretching pulses apply their gravitational impact with the velocity, V_F, of $10^{40} \cdot c$, which represents the extreme swiftness of the front spreading activity. It has been determined that a relatively slower removal of this impact by the succeeding rear activity, the desynchronization process, occurs with the velocity, V_r, of $10^{32} \cdot c$.

It is worthwhile to call attention to one of the most prominent cosmological consequences of the CAETERIS model. The "slow" periodic process, succession of Big Bangs, among other things gives an explanation the alleged acceleration of the Universe that has led to the concept of "dark energy". The situation is very simple: slow moving galaxies detected in the faraway cosmos had come from a previous Big Bang. This eradicates "dark energy", a substance even more mysterious than "dark matter".

7. **The distinction of gravitation from the rest of physics.** Gravitation is associated with the fast diffusion of phase. Commonly, diffusion processes handle monotonic parameters, like temperature and density, while the spread of gravitation use the periodic parameter of phase. However, as soon as the range of phase changes is significantly less than 2π the periodic nature of phase is not of importance. In contrast to gravitation, other types of material interactions involve sophisticated synchronization relationships, so they essentially deal with phase periodicity. These interactions show what is called local and global gauge invariance. The parameters comprising these synchro activities are not affected by different transformations that shift any phases by 2π and/or keep intact relative distribution of phases in the whole.

Gravitational force has the following characteristic properties: (1) long range, (2) instantaneous action-at-the-distance, (3) omnipresence, and (4) universal applicability to all sorts of material formations. Gravitational force is the cementing power of the Universe binding all the pieces of matter. Gravitation cannot be screened or modulated by any material process. The other three forces of Nature are basically different from gravitation in all aspects, except for the long range of electricity.

Electrostatic force resembles gravitation, as Coulomb's law looks mathematically equivalent to Newton's law. In the CAETERIS model the electrostatic force could be exercised as an "action-at-the distance" with stretching mediation agents as well. These mediating agents could be in the form of fast propagating cylinders emanating from the kernels; the generatrices of these cylinders come with circularly advancing phases having different senses of rotation determining the sign of electric charge. The scheme of stretching pulses is sensitive to jittering of their sources. For gravitation, this is a minor issue. For electrostatics, the falling apart stretching cylinders lead to vivid effects of

electrodynamics. At the outset we have considered a hypothesis that intersecting electrostatic stretching cylinders can generate gravitational constant phase lines as a secondary effect with a possible connection to "dark matter" (see a brief description and reference in [36]). Hypothetically, this could be of significance for the "Pioneer Anomaly" if it is a real physical effect. Long-range influences related to electrical effects might be involved in cosmological processes more than currently considered.

8. **Forces maintaining material synchro-formations.** The integrity of the traveling wave solutions presenting material synchro formations (Fig. 4) is provided by short-range forces against two basic ways of destruction: gentle separating of different parts of the kernel and restructuring of the whole kernel. The former transformations are associated with the so-called weak force, the latter – with the so-called strong force.

Synchronization presents a weak constraint that joints the kernels as if some delicate adhesive holds them together. Breaking up a kernel could be responsible for radioactive decay. Let us consider the momentous situation for the phase dependence in the kernel of a neutron. As shown in Fig. 5, taking the neutron kernel apart naturally produces the well-known scheme for neutron disintegration.

When kernels undergo significant transformations beyond slight separation of their parts substantial disturbances in material synchro activities can be generated. This might happen, for example, as a result of a head on collision of kernels with opposite sense of rotation for dual solutions of matter and antimatter. The disappearance of these material formations can be described in terms of conservation of mass-energy using the famous relationship: $E = mc^2$. Keeping together elementary synchro formations of matter involves complex issues that are associated with the strong force. Requirements for specific rotary shape impetuses in creation of kernels' helicoidal patterns translate into rotational restrictions – the conservation laws for charge, baryon, and lepton numbers.

9. **Falsification tests.** Following Karl Popper's ideas, a scientific theory to be established requires formulating an experimental test that could falsify it. As a theory withstands such negation attempts it becomes more and more acceptable. The presented mechanism of gravitation contains the distinctive property of non-locality: gravitational impact is exercised almost instantaneously producing what is called "action-at-the-distance". This translates into a categorical assertion that gravitational waves cannot exist. So far the suggested hypothesis withstands this test.

Besides the absence of gravitational waves our analysis allows making also a different firm prediction that "dark matter" particles do not exist: Fig. 5 shows the entire spectrum of stationary synchro formations and leaves no room for any other stable particle of this type. The upcoming investigations of elementary particles with a new powerful installation: the Large Hadron Collider (LHC) [41] are aimed, in particular, at revealing the "dark matter" in the form of Weakly Interacting Massive Particles (WIMP) that must be stable. Therefore, searching for WIMPs presents another falsification test for the whole surmised scheme of gravitation. Of course, the developed mechanism with amplified gravity makes the concept of the "dark matter" superfluous by itself.

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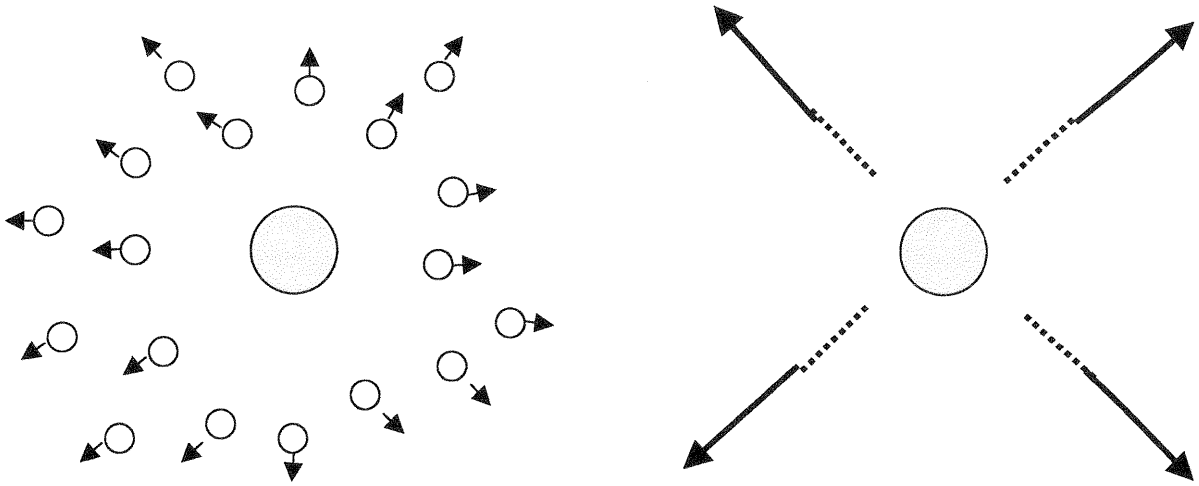


(a) (b)

Fig. 1

Different types of mediation agents:
restricted corpuscles and stretching pulses

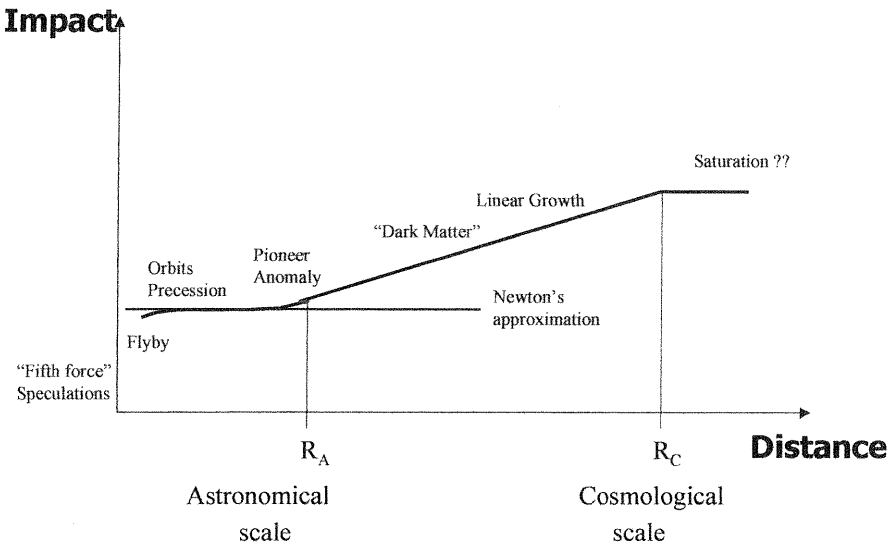


Fig. 2

Impact – distance diagram: the transfer function
for the gravitational mechanism with stretching pulses

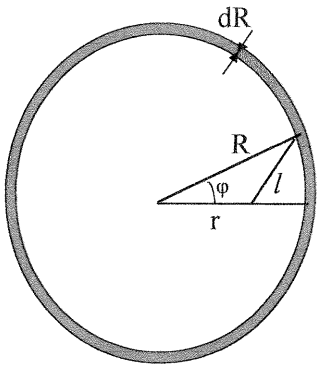
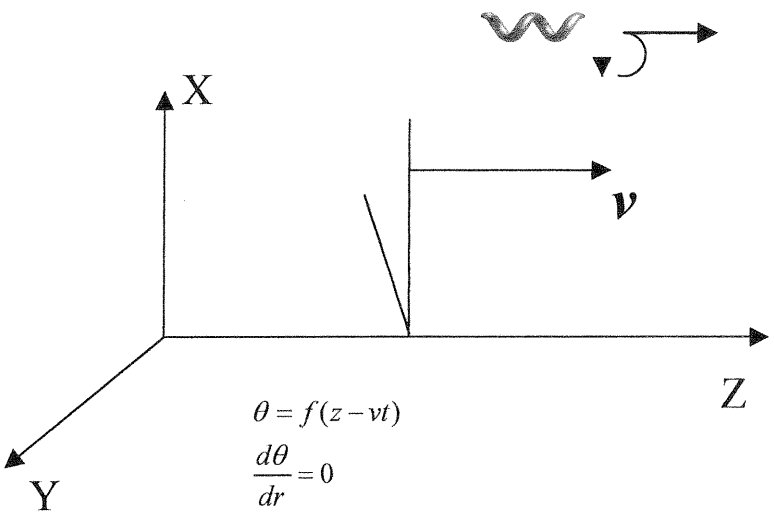


Fig. 3

Towards the analysis of the inverse-linear gravity:
an elemental spherical layer



The phase congruence condition for kernels:

Maximum speed - c

$$\theta = f(z - vt)$$

$$\frac{d\theta}{dr} = 0$$

$$\frac{d\theta}{d\varphi} = const$$

$$D_2\lambda^4 + D_1\lambda^2 + v\lambda - b = 0$$

$(^1/_{137} - 1) \cdot c$

Traveling waves – "quasi-particles" of matter

$$\theta = \frac{1}{(2D_1 \cdot \sqrt{\pi t^3})} \cdot \exp(-\frac{R^2}{4D_1 \cdot t} - bt)$$

$10^{40} \cdot c$

"Instantaneously" stretching phase lines – fast operational background

Fig. 4

Two types of the CAETERIS solutions:
ponderable material synchro formations and feeble non-locality

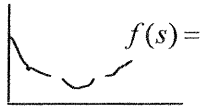
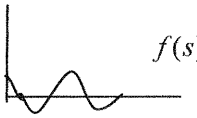
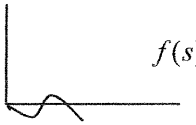
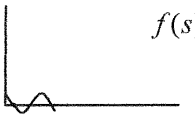
TYPES OF KERNELS	PHASE DEPENDENCES	PROPAGATION	
		intermittent V < C	continual V = C
Real exponents	Θ		
increasing	$f(s) = A_1 e^{\frac{b}{v}s}$	Proton	Electro-Magnetic Field
decreasing	$f(s) = A_2 e^{-\frac{v}{D_1}s}$	Electron	
combination	 $f(s) = A_1 e^{\frac{b}{v}s} + A_2 e^{-\frac{v}{D_1}s}$	Neutron → $e^- + \nu + p^+$	Photon
Imaginary exponents	θ		Neutrinos
	 $f(s) = A_3 \cos\sqrt{\frac{D_1}{D_2}}s$		*electron*
	 $f(s) = A_3 \cos\sqrt{\frac{D_1}{D_2}}s$		*tauon*
	 $f(s) = A_5 \cos\sqrt{\frac{D_3}{D_4}}s$		*muon*

Fig. 5

Stationary traveling wave solutions
correspond to the whole spectrum of stable elementary particles

GRAVITATIONAL WAVES

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Abstract

The proposed theory of gravitation is summarized, with a focus on dynamics. The linearized field equations are applied to gravitational waves. The theory predicts that longitudinal waves would be detected, which exert a force in the direction of propagation. It also explains the failure at LIGO and elsewhere to find transverse gravitational waves.

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1. Introduction.

This theory emphasizes the scalar nature of time and energy. The fundamental interval of kinematics

$$ds^2 = c^2dt^2 - d\mathbf{r}^2 \tag{1}$$

is invariant under a Lorentz transformation of the physical displacements $(dt,\ d\mathbf{r})$. The Lorentz transformation may take place at any point P, in flat or curved space-time. The vector $d\mathbf{r}$ is first projected onto an orthonormal 3-frame.[1] The projections, together with the scalar dt, are then transformed into new values, which are observed in a relatively moving frame. No coordinates are involved with this procedure.

Define the velocity $\mathbf{v} = d\mathbf{r}/dt$ in order to obtain

$$ds = c\,dt\sqrt{1 - \frac{v^2}{c^2}} \tag{2}$$

The energy and momentum

$$E = \frac{mc^2}{\sqrt{1 - v^2/c^2}} \qquad \mathbf{p} = \frac{m\mathbf{v}}{\sqrt{1 - v^2/c^2}} = \frac{E}{c^2}\mathbf{v} \tag{3}$$

form the invariant

$$m^2c^4 = E^2 - c^2\mathbf{p}^2 \tag{4}$$

Again, the momentum $\mathbf{p}$ may be projected onto an orthonormal 3-frame and, together with the scalar E, undergo a Lorentz transformation at point P. From (4), it follows that

$$E\frac{dE}{ds} = c^2\,\mathbf{p}\cdot\frac{d\mathbf{p}}{ds} \tag{5}$$

where constant rest mass is assumed. Substitute (3) to find

$$\frac{dE}{ds} = \mathbf{v}\cdot\frac{d\mathbf{p}}{ds} \tag{6}$$

This power formula and the momentum (3) make explicit use of the scalar, i.e., non-directional nature of energy.

[1] In the frame $\{\mathbf{ijk}\}$, the projections are $\mathbf{i}\cdot d\mathbf{r}$, $\mathbf{j}\cdot d\mathbf{r}$, and $\mathbf{k}\cdot d\mathbf{r}$.

2. Space, Time, Gravity. [1, 2]

An observer now introduces a coordinate system $\{x^\mu\}$, consisting of continuous space variables $\{x^i\}$ and synchronous clock readings $\{x^0\}$. In terms of these coordinates, the physical displacements are given by

$$c\,dt = e_0(x)dx^0 \qquad\qquad d\mathbf{r} = \mathbf{e}_i(x)dx^i \tag{7}$$

where $e_\mu = (e_0, \mathbf{e}_i)$ is a scalar, 3-vector basis. Substitution into the kinematic interval (1) yields

$$\begin{aligned} ds^2 &= (e_0 dx^0)^2 - \mathbf{e}_i \cdot \mathbf{e}_j\, dx^i dx^j \\ &= g_{\mu\nu} dx^\mu dx^\nu \end{aligned} \tag{8}$$

where

$$g_{\mu\nu} = \begin{pmatrix} g_{00} & 0 & 0 & 0 \\ 0 & & & \\ 0 & & g_{ij} & \\ 0 & & & \end{pmatrix} \tag{9}$$

is the scalar, 3-vector metric.

The basis system changes from point to point according to the formula

$$\nabla_\nu e_\mu = e_\lambda Q^\lambda_{\mu\nu} \tag{10}$$

This separates into scalar and 3-vector parts

$$\nabla_\nu e_0 = e_0 Q^0_{0\nu} \tag{11}$$

$$\nabla_\nu \mathbf{e}_i = \mathbf{e}_j Q^j_{i\nu} \tag{12}$$

By definition $Q^0_{j\nu} = Q^i_{0\nu} \equiv 0$, which leaves 40 components $Q^\mu_{\nu\lambda}$. The metrical functions satisfy

$$\partial_\lambda g_{\mu\nu} = g_{\mu\rho} Q^\rho_{\nu\lambda} + g_{\nu\rho} Q^\rho_{\mu\lambda} \tag{13}$$

or, in detail,

$$\partial_\lambda g_{00} = 2g_{00}Q^0_{0\lambda} \tag{14}$$
$$\partial_0 g_{ij} = g_{in}Q^n_{j0} + g_{jn}Q^n_{i0} \tag{15}$$
$$\partial_k g_{ij} = g_{in}Q^n_{jk} + g_{jn}Q^n_{ik} \tag{16}$$

The first expression may be inverted immediately

$$Q^0_{0\lambda} = \Gamma^0_{0\lambda} = \frac{1}{2}g^{00}\partial_\lambda g_{00} \tag{17}$$

The second may be inverted, if the two terms on the right-hand side are equal

$$Q^i_{j0} = \Gamma^i_{j0} = \frac{1}{2}g^{in}\partial_0 g_{nj} \tag{18}$$

Finally, Q^i_{jk} is assumed to be symmetric, in which case

$$Q^i_{jk} = \Gamma^i_{jk} = \frac{1}{2}g^{in}\left(\partial_k g_{jn} + \partial_j g_{nk} - \partial_n g_{jk}\right) \tag{19}$$

The additional conditions leave 28 independent $Q^\mu_{\nu\lambda}$. The Christofel coefficients

$$\Gamma^\mu_{\nu\lambda} = \frac{1}{2}g^{\mu\rho}\left(\partial_\lambda g_{\nu\rho} + \partial_\nu g_{\rho\lambda} - \partial_\rho g_{\nu\lambda}\right) \tag{20}$$

are symmetric in $\{\nu\lambda\}$, while the $Q^\mu_{\nu\lambda}$ are not. The following formula holds good

$$Q^\mu_{\nu\lambda} = \Gamma^\mu_{\nu\lambda} + g^{\mu\rho}g_{\lambda\eta}Q^\eta_{[\nu\rho]} \tag{21}$$

where

$$Q^\mu_{[\nu\lambda]} \equiv Q^\mu_{\nu\lambda} - Q^\mu_{\lambda\nu} \tag{22}$$

There are 9 independent components $Q^\mu_{[\nu\lambda]}$, namely

$$Q^0_{0i} = \frac{1}{2}g^{00}\partial_i g_{00} \qquad\qquad Q^i_{j0} = \frac{1}{2}g^{in}\partial_0 g_{nj} \tag{23}$$

The observer is free to introduce new coordinates $\{x^{\mu'}\}$. Although the space-time in question is generally time-dependent, at any point P the

new coordinates will be *at rest* with respect to the old. Thus, the physical displacements remain unchanged

$$c\,dt = e_0 dx^0 = e_{0'} dx^{0'} \qquad\qquad d\mathbf{r} = \mathbf{e}_i dx^i = \mathbf{e}_{i'} dx^{i'} \tag{24}$$

The new space coordinates are independent of clock rates, $x^{i'} = x^{i'}(x^j)$, and the new clock rates are independent of space coordinate labels, $x^{0'} = x^{0'}(x^0)$. These transformations determine the covariance of the theory. In particular, the metric tensor $g_{\mu\nu}$ transforms as

$$g_{0'0'} = \frac{\partial x^0}{\partial x^{0'}} \frac{\partial x^0}{\partial x^{0'}} g_{00} \qquad\qquad g_{i'j'} = \frac{\partial x^m}{\partial x^{i'}} \frac{\partial x^n}{\partial x^{j'}} g_{mn} \tag{25}$$

Moreover, $Q^{\mu}_{[\nu\lambda]}$ (23) transforms as a tensor

$$Q^{0'}_{0'i'} = \frac{\partial x^n}{\partial x^{i'}} Q^0_{0n} \qquad\qquad Q^{i'}_{j'0'} = \frac{\partial x^{i'}}{\partial x^m} \frac{\partial x^n}{\partial x^{j'}} \frac{\partial x^0}{\partial x^{0'}} Q^m_{n0} \tag{26}$$

This gravitational field strength tensor will play a central role in the theory to follow. Perhaps most importantly, it serves to define the gravitational energy tensor [1]

$$T^{(g)}_{\mu\nu} = \kappa \left\{ Q^{\rho}_{[\lambda\mu]} Q^{\lambda}_{[\rho\nu]} + Q_\mu Q_\nu - \frac{1}{2} g_{\mu\nu} g^{\eta\tau} (Q^{\rho}_{[\lambda\eta]} Q^{\lambda}_{[\rho\tau]} + Q_\eta Q_\tau) \right\} \tag{27}$$

where $Q_\mu = Q^{\rho}_{[\rho\mu]}$ and $\kappa = c^4/8\pi G$. For a static, Newtonian potential ψ

$$g_{00} = 1 + \frac{2}{c^2}\psi \tag{28}$$

so that $Q^{\mu}_{[\nu\lambda]}$ is given by

$$Q^0_{0i} = \frac{1}{c^2}\,\partial_i \psi \qquad\qquad Q^i_{j0} = 0 \tag{29}$$

It follows that

$$T^{(g)}_{00} = \frac{1}{8\pi G} (\nabla\psi)^2 \tag{30}$$

$$T^{(g)}_{0i} = 0 \tag{31}$$

$$T^{(g)}_{ij} = \frac{1}{4\pi G} \left\{ \partial_i \psi\, \partial_j \psi - \frac{1}{2} \delta_{ij} (\nabla\psi)^2 \right\} \tag{32}$$

which is the Newtonian stress-energy tensor.

3. Dynamics.

The equation of planetary motion

$$\frac{du^\mu}{ds} + \Gamma^\mu_{\nu\lambda} u^\nu u^\lambda = 0 \tag{33}$$

follows from the variation

$$\delta \int \sqrt{g_{\mu\nu} u^\mu u^\nu}\, ds = 0 \tag{34}$$

where $u^\mu = dx^\mu/ds$. Several components $\Gamma^\mu_{\nu\lambda}$ transform as tensors, suggesting that real gravitational forces are at work. This may be shown explicitly by calculating the rate of change of energy and momentum. From (2, 3, 7) it follows that, in coordinate terms,

$$E = mc^2 e_0 u^0 \qquad\qquad \mathbf{p} = mc\ \mathbf{e}_i u^i \tag{35}$$

The four-velocity $e_\mu u^\mu$ changes according to the formula

$$\frac{d(e_\mu u^\mu)}{ds} = e_\mu \frac{du^\mu}{ds} + \frac{de_\mu}{ds} u^\mu = e_\mu \left\{ \frac{du^\mu}{ds} + Q^\mu_{\nu\lambda} u^\nu u^\lambda \right\} \tag{36}$$

where $de_\mu = e_\lambda Q^\lambda_{\mu\nu} dx^\nu$ is Cartan's derivative operator.[3] Substitute (21) and make use of the equation of motion (33) to obtain

$$\frac{d(e_\mu u^\mu)}{ds} = e^\mu g_{\lambda\eta} Q^\eta_{[\nu\mu]} u^\nu u^\lambda \tag{37}$$

Separate this formula into scalar and 3-vector parts, then substitute (23) to find that the planet's energy and momentum change as follows:

$$\frac{dE}{ds} = e^0 \frac{mc^2}{2} \left\{ -\partial_n g_{00}\, u^n u^0 + \partial_0 g_{mn}\, u^m u^n \right\} \tag{38}$$

$$\frac{d\mathbf{p}}{ds} = \mathbf{e}^i \frac{mc}{2} \left\{ \partial_i g_{00}\, u^0 u^0 - \partial_0 g_{in}\, u^0 u^n \right\} \tag{39}$$

These formulas are exact. They express the power and force which are exerted by the gravitational field. They are not independent, since formula (6) is satisfied. In the Newtonian limit (28), $u^0 = 1$ and $u^n = v^n/c$ so that

$$\frac{dE}{dt} = -m\,\nabla\psi\cdot\mathbf{v} \qquad\qquad \frac{d\mathbf{p}}{dt} = -m\,\nabla\psi \tag{40}$$

The conservation law is established, by performing a similar calculation with the material energy tensor $T^{\mu\nu}_{(m)}$ (which may include any field other than gravity). The four-divergence of $\mathbf{T}_{(m)} = e_\mu \otimes e_\nu\, T^{\mu\nu}_{(m)}$ is given by [4]

$$\begin{aligned}\nabla\cdot\mathbf{T}_{(m)} &= e_\mu\left\{\frac{1}{\sqrt{-g}}\partial_\nu(\sqrt{-g}\,T^{\mu\nu}_{(m)}) + Q^\mu_{\nu\lambda}T^{\nu\lambda}_{(m)}\right\}\\ &= e_\mu\left\{\frac{1}{\sqrt{-g}}\partial_\nu(\sqrt{-g}\,T^{\mu\nu}_{(m)}) + \Gamma^\mu_{\nu\lambda}T^{\nu\lambda}_{(m)}\right\} + e^\mu g_{\lambda\eta}Q^\eta_{[\nu\mu]}T^{\nu\lambda}_{(m)}\end{aligned} \tag{41}$$

The first term is zero by virtue of the equations of motion, leaving

$$\nabla\cdot\mathbf{T}_{(m)} = e^\mu g_{\lambda\eta}Q^\eta_{[\nu\mu]}T^{\nu\lambda}_{(m)} \tag{42}$$

Once again, material energy and momentum are not conserved, due to the gravitational interaction. Therefore, introduce the energy tensor $T^{\mu\nu}_{(g)}$ in order to obtain

$$\begin{aligned}\nabla\cdot\left(\mathbf{T}_{(g)}+\mathbf{T}_{(m)}\right) &= e_\mu\left\{\frac{1}{\sqrt{-g}}\partial_\nu(\sqrt{-g}\,T^{\mu\nu}_{(g)}) + Q^\mu_{\nu\lambda}T^{\nu\lambda}_{(g)}\right\}\\ &\qquad + e^\mu g_{\lambda\eta}Q^\eta_{[\nu\mu]}T^{\nu\lambda}_{(m)} = 0\end{aligned} \tag{43}$$

This is the differential law of energy and momentum conservation. If gravity is negligible, then $T^{\mu\nu}_{(g)}$ and $Q^\mu_{[\nu\lambda]}$ are zero, and conservation follows from the equations of motion alone

$$\nabla\cdot\mathbf{T}_{(m)} = e_\mu\left\{\frac{1}{\sqrt{-g}}\partial_\nu(\sqrt{-g}\,T^{\mu\nu}_{(m)}) + \Gamma^\mu_{\nu\lambda}T^{\nu\lambda}_{(m)}\right\} = 0 \tag{44}$$

4. Gravitational Waves.

The gravitational field equations are derived by variation of the Einstein-Hilbert and material action

$$\delta\int\frac{\kappa}{2}\,g^{\mu\nu}R_{\mu\nu}\sqrt{-g}\,d^4x + \delta\int L^{(m)}\sqrt{-g}\,d^4x = 0 \tag{45}$$

where

$$R_{\mu\nu} = \partial_\nu \Gamma^\lambda_{\mu\lambda} - \partial_\lambda \Gamma^\lambda_{\mu\nu} + \Gamma^\lambda_{\rho\nu}\Gamma^\rho_{\mu\lambda} - \Gamma^\lambda_{\lambda\rho}\Gamma^\rho_{\mu\nu} \tag{46}$$

There are seven field equations, corresponding to the seven variations $\delta g^{\mu\nu} = (\delta g^{00}, \delta g^{ij})$

$$\kappa\Big(R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R\Big) + T^{(m)}_{\mu\nu} = 0 \tag{47}$$

Components R_{0i} and $T^{(m)}_{0i}$ do not appear.

In the weak-field approximation, the coordinate system is assumed to be nearly rectangular, $g_{\mu\nu} = \eta_{\mu\nu} + h_{\mu\nu}$, where the $h_{\mu\nu}$ are small compared with unity. Substitute into $R_{\mu\nu}$ and retain only the linear terms, to find

$$R_{\mu\nu} = \frac{1}{2}\left\{\eta^{\lambda\rho}\partial_\lambda\partial_\rho h_{\mu\nu} + \partial_\mu\partial_\nu h^\lambda_\lambda - \partial_\mu\partial_\lambda h^\lambda_\nu - \partial_\nu\partial_\lambda h^\lambda_\mu\right\} \tag{48}$$

In regions far from the source $T^{(m)}_{\mu\nu}$, one expects to find wave solutions of the equation

$$R_{\mu\nu} - \frac{1}{2}\eta_{\mu\nu} R = 0 \tag{49}$$

For motion along the x^3-axis, assume a solution of the form $h_{\mu\nu} = h_{\mu\nu}(x^0, x^3)$ to obtain

$$(R_{00} - \frac{1}{2}\eta_{00} R) = \frac{1}{2}\partial_3\partial_3(h^1_1 + h^2_2) = 0 \tag{50}$$

$$(R_{33} - \frac{1}{2}\eta_{33} R) = \frac{1}{2}\partial_0\partial_0(h^1_1 + h^2_2) = 0 \tag{51}$$

which shows that $h^1_1 + h^2_2 = 0$. Since $R = 0$, it follows that

$$R_{00} = \frac{1}{2}(\partial_0\partial_0 h^3_3 - \partial_3\partial_3 h^0_0) = 0 \tag{52}$$

$$R_{11} = \frac{1}{2}(\partial_0\partial_0 - \partial_3\partial_3) h_{11} = 0 \tag{53}$$

$$R_{22} = \frac{1}{2}(\partial_0\partial_0 - \partial_3\partial_3) h_{22} = 0 \tag{54}$$

$$R_{33} = -\frac{1}{2}(\partial_0\partial_0 h^3_3 - \partial_3\partial_3 h^0_0) = 0 \tag{55}$$

$$R_{12} = \frac{1}{2}(\partial_0\partial_0 - \partial_3\partial_3)h_{12} = 0 \tag{56}$$

$$R_{23} = \frac{1}{2}\partial_0\partial_0 h_{23} = 0 \tag{57}$$

$$R_{31} = \frac{1}{2}\partial_0\partial_0 h_{31} = 0 \tag{58}$$

The single condition $h^0_{\ 0} = h^3_{\ 3}$ is suggested by equations (52) and (55). This leaves three independent components which satisfy the wave equation

$$h_{00} = -h_{33} \quad h_{11} = -h_{22} \quad h_{12} = h_{21} \tag{59}$$

while $h_{23} = h_{31} = 0$.

The presence of the scalar component h_{00} is especially significant. According to (23, 27), the momentum density of a gravitational field is given by

$$\begin{aligned} T^{(g)}_{0i} &= \kappa(Q^0_{0n}Q^n_{i0} + Q^n_{n0}Q^0_{0i}) \\ &= \frac{\kappa}{4}\, g^{00}g^{mn}\left(\partial_n g_{00}\partial_0 g_{mi} + \partial_i g_{00}\partial_0 g_{mn}\right) \end{aligned} \tag{60}$$

This requires the existence of a spatially-dependent component g_{00}. In the wave field,

$$T^{(g)}_{03} = \frac{\kappa}{2}\,\partial_3 h^0_{\ 0}\,\partial_0 h^3_{\ 3} \tag{61}$$

which shows that *all* of the momentum is carried by the scalar-longitudinal field. The energy density is

$$\begin{aligned} T^{(g)}_{00} &= \frac{\kappa}{2}\left\{Q^m_{n0}Q^n_{m0} + Q^m_{m0}Q^n_{n0} - 2\eta^{mn}Q^0_{0m}Q^0_{0n}\right\} \\ &= \frac{\kappa}{4}\left\{(\partial_0 h^1_{\ 1})^2 + (\partial_0 h^1_{\ 2})^2 + (\partial_0 h^3_{\ 3})^2 + (\partial_3 h^0_{\ 0})^2\right\} \end{aligned} \tag{62}$$

There is energy in both transverse and longitudinal waves.

The scalar and longitudinal components possess energy and momentum. Therefore, the solution for h_{00} and h_{33} takes the form of a traveling wave, $a_L\cos(k^3x^3 - k^0x^0)$, where $k^0 = k^3$. It is readily shown that these components satisfy the energy conservation law (43), which is (to second order)

$$\partial_0 T^{00}_{(g)} + \partial_3 T^{03}_{(g)} = 0 \tag{63}$$

The transverse components h_{11}, h_{22}, h_{12} have no momentum, and the solution takes the form of a standing wave, $a_T \cos(k^3 x^3)\cos(k^0 x^0)$. In this case, conservation of energy is given by

$$\left\langle \partial_0 T^{00}_{(g)} \right\rangle = 0 \tag{64}$$

where the temporal average is taken.

The gravitational stress is given by

$$T^{(g)}_{ij} = \kappa \left\{ 2Q^0_{0i}Q^0_{0j} - \frac{1}{2}\eta_{ij}\left[\eta^{00}(Q^m_{n0}Q^n_{m0} + Q^m_{m0}Q^n_{n0}) + 2\eta^{mn}Q^0_{0m}Q^0_{0n}\right]\right\} \tag{65}$$

which is diagonal in the wave field

$$T^{(g)}_{11} = T^{(g)}_{22} = \frac{\kappa}{4}\left[(\partial_0 h^1{}_1)^2 + (\partial_0 h^1{}_2)^2\right] \tag{66}$$

$$T^{(g)}_{33} = \frac{\kappa}{2}(\partial_3 h^0{}_0)^2 + \frac{\kappa}{4}\left[(\partial_0 h^1{}_1)^2 + (\partial_0 h^1{}_2)^2\right] \tag{67}$$

These stresses are compressive, with the transverse standing wave exerting an equal pressure in all directions, and the longitudinal traveling wave exerting pressure along the direction of propagation. The longitudinal components satisfy the momentum conservation law

$$\partial_0 T^{30}_{(g)} + \partial_3 T^{33}_{(g)} = 0 \tag{68}$$

while the transverse components satisfy

$$\left\langle \partial_3 T^{33}_{(g)} \right\rangle = 0 \tag{69}$$

where the spatial average is taken.

Finally, the force exerted by the gravitational wave is found by substituting $h_{\mu\nu}$ into the momentum equation (39)

$$\frac{d\mathbf{p}}{dt} = -\frac{mc^2}{2}\Big\{\mathbf{i}_1\Big(\partial_0 h^1{}_1\frac{v^1}{c} + \partial_0 h^1{}_2\frac{v^2}{c}\Big) + \mathbf{i}_2\Big(\partial_0 h^2{}_1\frac{v^1}{c} + \partial_0 h^2{}_2\frac{v^2}{c}\Big) + \mathbf{i}_3\Big(\partial_3 h^0{}_0 + \partial_0 h^3{}_3\frac{v^3}{c}\Big)\Big\} \tag{70}$$

If the detector is initially at rest, then $v^n = 0$, and the acceleration will be along the direction of propagation

$$\frac{d^2x^3}{dt^2} = -\frac{c^2}{2}\,\partial_3 h^0_{\ 0} \tag{71}$$

5. Concluding Remarks.

The experiments at LIGO, GEO, and Virgo have found no trace of transverse gravitational waves. This is explained by equation (70), which shows that the transverse forces are zero, if the detector is at rest. Detection is completely dominated by the longitudinal term.

In this theory, the energy and momentum are well-defined for particles and fields, including the gravitational field itself. The treatment of particle dynamics resembles that of special relativity. It begins with the Lorentz transformation, which serves to establish the relativistic expressions for energy and momentum. A coordinate basis is then introduced, which is free to vary from point to point in space-time. This non-uniformity is responsible for the energy, momentum, and stress of the gravitational field. Moreover, it is physically observed as the force of gravitation. The non-uniformity is embodied in the field strength tensor $Q^{\mu}_{[\nu\lambda]}$, which is the fundamentally new element in the theory. It appears in the gravitational energy tensor (27), the gravitational force (37), and the conservation law (43).

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A PRELIMINARY ATTEMPT ON THE REFRAMING OF THERMODYNAMICS OF IRREVERSIBLE PROCESSES USING SANTILLI'S HADRONIC MECHANICS

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Abstract

Following decades of research, R. M. Santilli [1-6] has achieved a genotopic (that is, axiom inducing) lifting of 20th century mathematics with a Lie algebra structure as used for reversible systems into a covering Lie-admissible form which is irreversible beginning with basic multiplications and related units, today's known as *Santilli genomathematics*. On the basis of these studies, we introduce apparently for the first time the genotopic lifting of the known Clausius inequality and the fluid-dynamical internal energy balance equation. Then, beginning with this *geno-Clausius inequality* we introduce the *geno-entropy function* in its time rate form. Next, on combining the geno-entropy equation with the geno-internal energy balance equation, we generate the *geno-Gibbs relation* as well as the *geno-De Donderian equation.* In this way, all thermodynamic equations are obtained as invariant to the time reversal operation – in perfect conformity with what is observed in nature, the understanding being that the irreversibility of the emerging novel *geno-thermodynamics* is set by the axioms of the underlying mathematcs.

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1 INTRODUCTION

Following decades of research, R. M. Santilli [1] has achieved a genotopic (that is, axiom inducing) lifting of 20th century mathematics with a Lie algebra structure as used for reversible systems into a covering Lie-admissible form which is irreversible beginning with basic multiplications and related units, known as *Santilli genomathematics*, which is particularly suited for quantitative treatment of thermodynamical processes of matter due to their irreversibility. Santilli has also identified an important subclass of genomathematics, also used for the description of thermodynamical processes of matter, which is an isotopic (that is, axiom-preserving) lifting of 20th century Lie mathematics with a Lie-isotopic structure, today known as *Santilli's isomathematics*. Finally, Santilli has discovered an anti-Hermitean map, called isoduality, for the description of antimatter, resulting in the novel *isodual genomathematics* and *isodual isomathematics*, that have permitted the first known initiation of thermodynamical studies for antimatter. To avoid a prohibitive length, we assume a technical knowledge of geno- and iso-mathematics for matter and their isoduals for antimatter as presented in Refs. [1–6]. Also Santilli proved the following basic theorem, namely:

NO REDUCTION THEOREM:

> ***A classical system that is irreversible over time cannot be consistently reduced to a finite number of elementary particles all reversible over time and, vice-versa, a finite number of elementary particles all in reversible conditions cannot yield a macroscopic irreversible event under the correspondence or other principles.***

The above theorem has far reaching implications on bridging macroscopic and microscopic domains of physical descriptions. Moreover, it has been shown by Dunning-Davies [7, 8] that the existing thermodynamic structure, for example the first and second law of thermodynamics based equation, namely:

$$TdS = dU + pdV \tag{1}$$

conforms well with Santilli's iso-, isodual- and geno- mathematics and accommodates well also the systems composed of antimatter and for that matter even the Gibbs relation, namely:

$$TdS = dU + pdV - \mu\, dN \tag{2}$$

remains valid.

2 THE NEW THERMODYNAMICS

The applications of geno-, iso- and isodual mathematics to thermodynamics available at this writing are those in Refs. [7–11], and can be summarized as follows.

2.1 Iso-thermodynamics for matter

$$TdS = T \times dS \to \widehat{T} \,\widehat{\times}\, \widehat{dS} \to T \times \widehat{I} \times \widehat{K} \times \widehat{dS} \to T \times \widehat{dS}, \tag{3}$$

where

$$I \to \widehat{I} = \frac{1}{\widehat{K}} > 0$$

is the Hermitean *isounit* and T the *isotopic element* at the foundation of Santilli's isomathematics. Then

$$T \times dS \to T \times \widehat{dS} = T \times \widehat{I} \times d\left(S \times \widehat{I}\right) = \widehat{I} \times TdS. \tag{4}$$

Hence, it follows immediately that,

$$\begin{aligned} dQ &= dU + pdV \to \widehat{dQ} = \widehat{dU} + \widehat{p} \times \widehat{dV} \to \widehat{I} \times dQ \\ &= \widehat{I} \times (dU + pdV) \Rightarrow dQ = dU + pdV \end{aligned}$$

and

$$dQ = TdS \to \widehat{dQ} = \widehat{T} \,\widehat{\times}\, \widehat{dS} \to \widehat{I} \times dQ = \widehat{I} \times TdS \Rightarrow dQ = TdS.$$

This then demonstrates that, within the iso-mathematical framework, the equations representing the first and second laws of thermodynamics

hold in their familiar forms. This also confirms that all standard thermodynamic relations and equations would retain their familiar forms in iso-mathematics' framework, namely:

$$TS = U + pV - \mu N,$$

the Gibbs-Duhem equation:

$$SdT - Vdp + Nd\mu = 0,$$

the Gibbs relation:

$$dS = T^{-1}dU + pT^{-1}dV - \mu T^{-1}dN,$$

and so on.

2.2 Geno-thermodynamics for matter

The conformity of the standard thermodynamic relations and equations with geno-mathematics is demonstrated as follows.

$$TdS = dU + pdV \rightarrow T^{>} > d^{>}S^{>} = d^{>}U^{>} + p^{>}d^{>}V^{>} \tag{5}$$

where $I^{>} = 1/T^{>}$ is the generally non-Hermitean *genounit* and $T^{>}$ is thge *genotopic element* at the foundation of Santilli's genomathematiucs. The above expression can be written

$$\begin{aligned} (TI^{>})\, I^{>-1}\left[I^{>-1}d\,(SI^{>})\right] &= TdS \\ &= I^{>-1}d\,(UI^{>}) \\ &\quad + (pI^{>})\, I^{>-1}\left[I^{>-1}d\,(VI^{>})\right] \\ &= dU + pdV. \end{aligned}$$

If the geno-unit depends on the local variables, we have,

$$dS \rightarrow d^{>}S^{>} = I^{>-1}d\,(SI^{>}) = dS + SI^{>-1}dI^{>}$$

and similarly for dQ and dW. Hence we have the following transformations,

$$\begin{gathered} T^{>} > d^{>}S^{>} = d^{>}U^{>} + p^{>} > d^{>}V^{>} \rightarrow \\ \rightarrow TdS + TSI^{>-1}dI^{>} = \\ = dU + UI^{>-1}dI^{>} + pdV + pVI^{>-1}dI^{>} \Rightarrow \\ \Rightarrow TdS = dU + pdV, \end{gathered}$$

since $TS = U + pV$. Thus whether the geno-unit is independent or dependent on the local variables the form of the standard thermodynamic relations retain their forms in geno-mathematics.

2.3 Isodual-thermodynamics for antimatter

Dunning-Davies [7] also demonstrated that Santilli's anti-Hermitean Isodualities, denoted with the upper symbol ^{d} lead us to the thermodynamics of antimatter for which the standard thermodynamic relations retain their forms. The demonstration follows the following steps.

$$\begin{aligned} dQ \rightarrow d^dQ^d &= dQ,\ dU \rightarrow d^dU^d = dU, \\ dW \rightarrow d^dW^d &= dW,\ dS \rightarrow d^dS^d = dS \end{aligned} \tag{6}$$

as we have the following isoduality transformations,

$$\begin{gathered} df \rightarrow d^df^d = -d\left[-f\right],\ +1 \rightarrow -1 = 1^d, \\ \therefore\ 1^d \times^d n = (-1) \times (-1)n = n \end{gathered}$$

that produces:

$$\begin{gathered} Q \rightarrow Q^d = -Q,\ U \rightarrow U^d = -U,\ W \rightarrow W^d = -W, \\ S \rightarrow S^d = -S,\ T \rightarrow T^d = -T. \end{gathered}$$

On using above transformations the following gets established:

$$dQ \rightarrow d^dQ^d = dQ = dU - dW \rightarrow d^dU^d - d^dW^d = dU - dW.$$

That is, the First law of thermodynamics is **isoselfdual**. Similarly,

$$dQ \rightarrow d^dQ^d = dQ = TdS \rightarrow T^d \times^d d^dS^d = (-T) \times (-1)dS = TdS.$$

Therefore, $TdS = dU - dW$ and $TdS = dU + pdV - \mu dN$ are **isoselfdual**. That is they are equally valid for antimatter too including the Gibbs-Duhem equation, $SdT - Vdp + Nd\mu = 0$.

3 THE NEED FOR AN AB INITIO APPROACH OF DEVELOPING GENO-THERMODYNAMICS

In this paper, we carry forward, apparently for the first time, the above initial investigations to an ab initio isotopy, genotopy and isoduality of conventional 20th century thermodynamics. As it is well known, for every thermodynamic nonequilibrium situation the traditional definition $dQ = TdS$ is not valid. Hence, we need to first define corresponding entropy function using the mathematical expressions that takes care of the existing irreversibility. The best candidate for this is Clausius' inequality. The aspects that we initially propose to handle, which is expected to streamline the subject of nonequilibrium thermodynamics as recently reiterated by the present author [12], are listed below.

1. Re-express Clausius' inequality [13], namely:

$$\oint_{irr} \frac{dQ}{T_R} < 0 \qquad \text{(closed systems)} \tag{7}$$

and its generalized version [12,14,15], namely:

$$\oint_{irr} \left[\frac{1}{T_R(t)} \frac{dQ}{dt}\right] dt$$

$$\equiv \oint_{irr} \left[\int_A -\frac{\mathbf{Q}(\mathbf{A},t)}{T(\mathbf{A},t)} \cdot \mathbf{dA}\right] dt < 0 \ \text{(closed systems)} \tag{8}$$

using geno-mathematics.

2. Generate the entropy function appropriate for nonequilibrium from the so modified versions of Clausius' inequality both for spatially uniform and non-uniform systems.

3. Incorporate the local level fluid-dynamical and global level internal energy balance equations that has been re-expressed using geno-mathematics to generate geno-mathematics based corresponding Gibbs relations.

4. In doing so the dictates of the "universe of operations of thermodynamics" as revealed by Bridgman [16, 17] and the present author [12, 18, 19] need to be appropriately followed.

5. An amicable incorporation of the generalized zeroth law of thermodynamics given and legitimized temperature function in nonequilibrium [12, 15, 20] in this geno-thermodynamics structure.

6. To apply the so generated thermodynamic structure to varied types of systems in nonequilibrium made up on the one hand of matter and the other hand of antimatter to begin with.

7. To investigate corresponding statistical implications. This would demand a reformulation of the celebrated Boltzmann integro-differential equation using geno-mathematics and then study its implication on the famous Boltzmann H-theorem as well as to rigorously establish an unambiguous connection between the Boltzmann H-function and the thermodynamic geno-entropy function obtained by geno-mathematics.

Moreover, we need to consider that when all global irreversible descriptions have their roots in the irreversible description at the molecular level then how the global reversible description (say the traditional thermodynamics) gets generated from the molecular level irreversible description on imposing the condition of reversibility on a given global system. The answer would perhaps lie in $I^{>} = {}^{<}I$ and/or $I^{f} = {}^{b}I$ at molecular level for geno-numbers of their motion. But then how this equivalence gets generated by simply imposing equilibrium conditions globally needs to be understood.

4 A PRELIMINARY ATTEMPT

In geno-mathematics equations (7) and (8) would get expressed as,

$$\oint \frac{d^{>}Q^{>}}{T_R^{>}} < 0 \qquad \text{(closed systems)} \tag{9}$$

$$\oint \left[\frac{1}{T_R^{>}} > \frac{d^{>}Q^{>}}{d^{>}t^{>}}\right] d^{>}t^{>}$$

$$\equiv \oint \left[\int_A -\frac{\mathbf{Q}^{>}(\mathbf{A}^{>})}{T^{>}(\mathbf{A}^{>})} \cdot \mathbf{d}^{>}\mathbf{A}^{>}\right] > d^{>}t^{>} < 0 \text{ (closed systems).} \tag{10}$$

Notice that the subscript irr below the cyclic integration sign has been omitted because it has become redundant as well as the explicit time dependence of heat flux vector and temperature function is not required to be shown.

We also need the fluiddynamical internal energy balance equation derived in geno-space. The per unit mass momentum balance equation in geno-space for a control volume of the fluid reads as,

$$\rho^{>} > \frac{d^{>}\mathbf{v}^{>}}{d^{>}t^{>}} = \mathbf{F}^{>} + \nabla^{>} \cdot \mathbf{T}^{>} \tag{11}$$

where $\rho^{>}$ is the mass density, $\mathbf{v}^{>}$ is the barycentric velocity, $\mathbf{F}^{>}$ is the per unit mass body force determined by the corresponding potential field and $\mathbf{T}^{>}$ is the stress tensor or momentum flux due to contact forces.

Now for the sake of simplicity we consider systems where body forces contribute a little and manipulate eq.(11) that produces following internal energy balance equation, namely:

$$\rho^{>} > \frac{d^{>}u^{>}}{d^{>}t^{>}} = -\nabla^{>} \cdot \mathbf{q}^{>} - p^{>} > \rho^{>} > \frac{d^{>}v^{>}}{d^{>}t^{>}} + \mathbf{\Pi}^{>} : \nabla^{>}\mathbf{v}^{>} \tag{12}$$

where $u^{>}$ is the per unit mass internal energy, $\mathbf{q}^{>}$ is the local density of heat flux, $p^{>}$ is the local fluid pressure, $v^{>}$ is the specific volume and $\mathbf{\Pi}^{>}$

is the dissipative stress tensor. Now we are well equipped to reframe nonequilibrium thermodynamic framework in geno-space that we term as Geno-Generalized Phenomenological Irreversible Thermodynamic Theory (Geno-GPITT), which we describe in next subsection.

4.1 Geno-GPITT

4.1.1 Geno-entropy

Now on following the steps identical to those described from equation (88) onwards in reference [12] we obtain the following expression of *geno-entropy*, $S^{>}$, from the above eq.(10) as,

$$\frac{d^{>}S^{>}}{d^{>}t^{>}} = \int\limits_{V^{>}} \left[-\nabla^{>}\cdot\left(\frac{\mathbf{q}^{>}}{T^{>}}\right) + \mathbf{q}^{>}\cdot\nabla^{>}\left(\frac{1}{T^{>}}\right)\right] > d^{>}V^{>} + \frac{d^{>}N^{>}}{d^{>}t^{>}}. \tag{13}$$

Thus from eq.(13) we have in the notation of Belgian school, the following expression for *rate of exchange of geno-entropy*, namely:

$$\frac{d_e^{>}S^{>}}{d^{>}t^{>}} = \int\limits_{V^{>}} \left[-\nabla^{>}\cdot\left(\frac{\mathbf{q}^{>}}{T^{>}}\right)\right] > d^{>}V^{>} \lesseqgtr 0 \tag{14}$$

and the *rate of production of geno-entropy* is given by,

$$\frac{d_i^{>}S^{>}}{d^{>}t^{>}} = \int\limits_{V^{>}} \left[\mathbf{q}^{>}\cdot\nabla^{>}\left(\frac{1}{T^{>}}\right)\right] > d^{>}V^{>} + \frac{d^{>}N^{>}}{d^{>}t^{>}} \geq 0. \tag{15}$$

Notice that the time rate of change of *geno-uncompensation function*, $d^{>}N^{>}/d^{>}t^{>}$ (> 0) is as dictated by Clausius' inequality and the integral on the right hand side of eq.(15) is positive definite as its integrand is positive definite hence eq.(15) describes the *rate of geno-entropy production*.

At this juncture one may ask that – **what new has been achieved in the preceding description**? – because if one compares preceding equations with the corresponding expressions/equations of reference [12] he

would find that they are exactly the same except for the use of superscript (>) to the quantities in the above description. To answer this seemingly objection, one needs to recall that the equations of reference [12], and for that matter of traditional nonequilibrium thermodynamics, are based on the traditional Newtonian mechanics. Wherein, the time reversal is effected by substituting $-t$ for t. However, when this is effected the signs of time rate of change of entropy, of entropy exchange and that of entropy production also change their signs. But then this would imply that the occurring processes would start proceeding in reverse direction, which is not at all in tune with the reality. On the other hand in geno-mathematics the time reversal is effected by basing the mathematical description on ${}^{<}I$ and $<$ instead of $I^{>}$ and $>$ where by definition $I^{>} \neq {}^{<}I$. That is the forward and reverse trajectories are not the same, perfectly in tune with the reality.

4.1.2 Geno-Gibbs relation

Let us consider, for the sake of simplicity, a system having irreversibility only on account of heat transfer that is due to the existence of temperature gradient. Because the system is spatially non-uniform we need to go for the local level description. Hence, by using the following relations, namely:

$$\frac{d^{>}S^{>}}{d^{>}t^{>}} = \int\limits_{V^{>}} \rho^{>} > \frac{d^{>}s^{>}}{d^{>}t^{>}} > d^{>}V^{>} \tag{16}$$

and

$$\frac{d^{>}N^{>}}{d^{>}t^{>}} = \int\limits_{V^{>}} \rho^{>} > \frac{d^{>}\mathcal{N}^{>}}{d^{>}t^{>}} > d^{>}V^{>}, \tag{17}$$

from eq.(13) we obtain,

$$\rho^{>} > \frac{d^{>}s^{>}}{d^{>}t^{>}} = -\nabla^{>} \cdot \left(\frac{\mathbf{q}^{>}}{T^{>}}\right) + \mathbf{q}^{>} \cdot \nabla^{>} \left(\frac{1}{T^{>}}\right) + \rho^{>} > \frac{d^{>}\mathcal{N}^{>}}{d^{>}t^{>}} \tag{18}$$

where $s^{>}$ is the *per unit mass geno-entropy* and $\mathcal{N}^{>}$ is the per unit mass *geno-uncompensation function*. Now to quantify $\mathcal{N}^{>}$ we combine eq.(18)

with eq.(12) that produces,

$$\rho^{>} > \frac{d^{>}s^{>}}{d^{>}t^{>}} = \frac{1}{T^{>}} > \left[\rho^{>} > \frac{d^{>}u^{>}}{d^{>}t^{>}} + p^{>} > \rho^{>} > \frac{d^{>}v^{>}}{d^{>}t^{>}} + \mathbf{\Pi}^{>} : \nabla^{>}\mathbf{v}^{>}\right] + \rho^{>} > \frac{d^{>}\mathcal{N}^{>}}{d^{>}t^{>}}. \tag{19}$$

Next on following the steps and considerations described in the article cited at the reference number [12] from its eq.(100) onwards, that involves the use of the relevant expressions from the kinetic theory of gases and the expressions proposed therein for chemical potentials and mass fractions of the molecules, the following **geno-Gibbs relation** is obtained, namely:

$$\frac{d^{>}s^{>}}{d^{>}t^{>}} = \frac{1}{T^{>}} > \frac{d^{>}u^{>}}{d^{>}t^{>}} + \frac{p^{>}}{T^{>}} > \frac{d^{>}v^{>}}{d^{>}t^{>}} - \beta^{>} > \mathbf{q}^{>} \cdot \frac{d^{>}\mathbf{q}^{>}}{d^{>}t^{>}} \tag{20}$$

accompanied by the corresponding **geno-Gibbs-Duhem equation**, namely:

$$\frac{d^{>}((\mu^{>})^{(\ominus)}/m^{>})}{d^{>}t^{>}} + \left(s^{>} - \frac{\beta^{>}}{2^{>}}(q^{>})^{2^{>}}\right)\frac{d^{>}T^{>}}{d^{>}t^{>}} - \left(v^{>} + \frac{\beta^{>}}{2^{>}}(q^{>})^{2^{>}}\right)\frac{d^{>}p^{>}}{d^{>}t^{>}} = 0 \tag{21}$$

where,

$$\beta = \frac{4}{5npk_BT^2} \tag{22}$$

with n being the number density of the molecules and

$$\frac{d^{>}\mathcal{N}^{>}}{d^{>}t^{>}} = -\beta^{>} > \mathbf{q}^{>} \cdot \frac{d^{>}\mathbf{q}^{>}}{d^{>}t^{>}}. \tag{23}$$

Further, eq.(20) gets also expressed in *geno-entropy balance form* as,

$$\rho^{>} > \frac{d^{>}s^{>}}{d^{>}t^{>}} = -\nabla^{>} \cdot \left(\frac{\mathbf{q}^{>}}{T^{>}}\right) + \mathbf{q}^{>} \cdot \nabla^{>}\left(\frac{1}{T^{>}}\right) - \beta^{>} > \rho^{>} > \mathbf{q}^{>} \cdot \frac{d^{>}\mathbf{q}^{>}}{d^{>}t^{>}} \tag{24}$$

that provides the following expressions of *geno-entropy flux density*, $\mathbf{J}^{>}_{s^{>}}$, as:

$$\mathbf{J}^{>}_{s^{>}} = \left(\frac{\mathbf{q}^{>}}{T^{>}}\right) \tag{25}$$

and the *geno-entropy source strength*, $\sigma^{>}_{s^{>}}$, as:

$$\sigma^{>}_{s^{>}} = \mathbf{q}^{>} \cdot \nabla^{>}\left(\frac{1}{T^{>}}\right) - \beta^{>} > \rho^{>} > \mathbf{q}^{>} \cdot \frac{d^{>}\mathbf{q}^{>}}{d^{>}t^{>}} \geq 0. \tag{26}$$

Notice that we have included the rate of change of geno-heat flux term as such in the expression of *geno-entropy source strength* that restricts the use of constitutive equations of the rate of change of geno-heat flux. That is it should be devoid of divergence term, such as the geno-version of Maxwell-Cattaneo-Vernotte equation [21,22], namely:

$$\rho^{>} > \frac{d^{>}\mathbf{q}^{>}}{d^{>}t^{>}} + \mathbf{q}^{>} = -\lambda^{>} > \nabla^{>}T^{>}$$

Notice that in all the preceding equations the invariance under time evolution is meticulously maintained as we have used throughout the genotopically lifted equations.

4.1.3 Geno-De Donderian equation

In this case we have spatially uniform systems and the irreversibility is that due to the occurrence of chemical conversions at finite rates. This then does not require the local level considerations. We have to manipulate geno-mathematics at the global level of consideration. Therefore, eq.(13), in present case reduces to,

$$\frac{d^{>}S^{>}}{d^{>}t^{>}} = \frac{1}{T^{>}} > \frac{d^{>}Q^{>}}{d^{>}t^{>}} + \frac{d^{>}N^{>}}{d^{>}t^{>}}. \tag{27}$$

The *geno-uncompensation function* in the case of a single chemical reaction taking place at a finite rate gets quantified as,

$$\frac{d^{>}N^{>}}{d^{>}t^{>}} = \frac{\mathcal{A}^{>}}{T^{>}} > \frac{d^{>}\xi^{>}}{d^{>}t^{>}} \geqslant 0 \tag{28}$$

where $\mathcal{A}^>$ is the *geno-chemical affinity* and the *geno-extent of advancement of the chemical reaction*, $\xi^>$, is related with the mole number changes of the reactants and products by Dalton's law as:

$$\frac{d^> n_k^>}{d^> t^>} = \nu_k^> > \frac{d^> \xi^>}{d^> t^>} \tag{29}$$

where $\nu_k^>$ is the *geno-stoichiometric number* and $n_k^>$ is the *geno-mole number of the component* k. The corresponding internal energy balance equation reads as,

$$\frac{d^> U^>}{d^> t^>} = \frac{d^> Q^>}{d^> t^>} - p^> > \frac{d^> V^>}{d^> t^>}. \tag{30}$$

Therefore, from equations (27) - (30) we arrive at the following **geno-De Donderian equation**, namely:

$$\frac{d^> S^>}{d^> t^>} = \frac{1}{T^>} > \frac{d^> U^>}{d^> t^>} + \frac{p^>}{T^>} > \frac{d^> V^>}{d^> t^>} + \frac{\mathcal{A}^>}{T^>} > \frac{d^> \xi^>}{d^> t^>} \tag{31}$$

along with the corresponding **geno-Gibbs-Duhem equation**, namely:

$$S^> \frac{d^> T^>}{d^> t^>} - V^> \frac{d^> p^>}{d^> t^>} + \sum_k n_k^> \frac{d^> \mu_k^>}{d^> t^>} = 0. \tag{32}$$

Again notice the meticulous maintenance of invariance under time evolution in all the above equations.

5 CONCLUDING REMARKS

The aim of this article was the initiation of systematic studies toward a "structurally irreversible" formulation of thermodynamics, that is, a formulation based on a mathematics admitting two versions, one for motion forward in time and the other for motion backward in time, irreversibility of thermodynamical laws being assured by the inequivalence of the two formulations.

In this paper we have shown that the above primary objective can indeed be achieved thanks to *Santilli Lie-admissible mathematics*, also

known as *geno-mathematics*. In fact, the indicated objective can begin with the genotopic lifting of Clausius' inequality and then pass to the systematic formulation of *geno-thermodynamics* for irreversible processes that perfectly stands the test of invariance under time evolution, the one that is the basic feature of all natural processes.

As in this paper we have used the steps of derivation described by eq.(88) and onwards of the article cited at reference number [12], the present development of the geno-thermodynamics meets well the demands of the realm of the universe of operations of thermodynamics as conjectured by Bridgmann [12, 15–18] and also uses the temperature function based on generalized zeroth law of thermodynamics [20]. This success in turn opens the door to begin systematic investigations of various aspects of irreversibility at thermodynamic level, mesoscopic and microscopic levels and their interconnections, including a much needed thermodynamical formulation directly compatible with mechanics as initially studied by Santilli [1,2].

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